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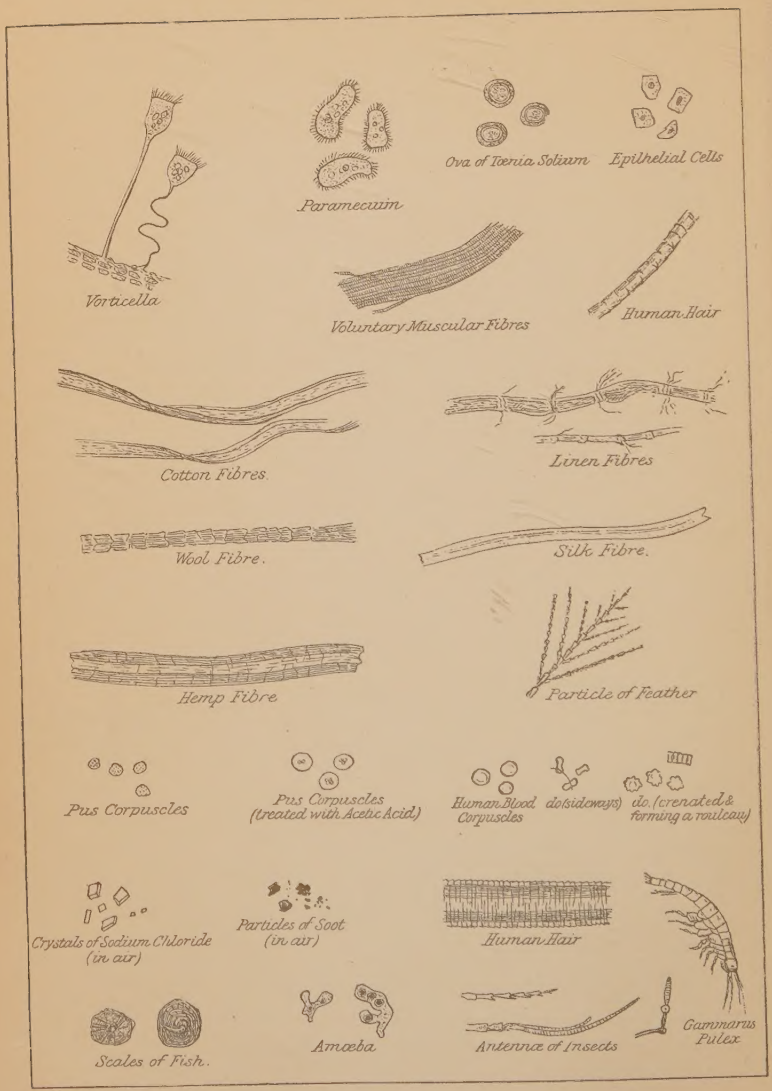
PUBLIC HEALTH LABORATORY WORK

PLATE I



Objects commonly found in impure water (and air).

PUBLIC HEALTH

LABORATORY WORK

BY

HENRY R. KENWOOD, M.B.

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INCLUDING

METHODS EMPLOYED IN BACTERIOLOGICAL RESEARCH, WITH SPECIAL REFERENCE TO THE EXAMINATION OF AIR, WATER AND FOOD

CONTRIBUTED BY

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WITH ILLUSTRATIONS

PHILADELPHIA

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PREFACE.

The matter contained within these pages is broadly that which is taught, under the direction of Professor Corfield, in the Practical Hygiene Course at University College. It is hoped that the book will prove of value to those interested in Public Health, and to those seeking Public Health degrees, and that it may be read along with the many excellent works upon Hygiene and Public Health which are now in circulation, but which of necessity deal with the subject of hygienic analyses in far too cursory a manner.

An effort has been made to convey to the reader, in a concise and practical form, the knowledge necessary to enable him to make those analyses which may be fairly considered to be included within the domains of practical hygiene. To treat the subject *exhaustively* would necessitate a very bulky volume, and those who recognise the breadth of subject matter embraced by the title "Public Health Laboratory Work," will appreciate that it has been found necessary, in the present volume, to avoid all discursive matter save what is required to make the rationale of a process evident, and where there are several processes in vogue to one common end, to select that one which experience has taught to be at the same time the most simple, ready and efficient—to the exclusion of all others.

It has not been an easy task, in every case, to decide as to what should be included and what omitted.

There are, for instance, several recent and somewhat improved methods of estimating the carbonic acid in air, but the process of Pettenkofer has become what one may term "classical," and is that which is still generally asked in Public Health Examinations; and since the method is sufficiently accurate, when carefully performed, for all practical purposes, it was thought advisable to introduce it to the exclusion of others.

The subject of hygienic analysis will be seen to dovetail itself into the work of the Public Analyst, but not to such an extent, it is held, as to render that officer any the less essential to a district.

The writer acknowledges his great indebtedness to the useful contribution on bacteriological methods by Dr. Boyce, for he recognises how much this enhances the value of the work; he desires also to express his thanks for many kind and valuable suggestions from Professor Corfield, Dr. Louis C. Parkes and Dr. Braga.

He is further indebted to Dr. Louis C. Parkes for the use of figures 51, 52, 55, 58, 60 to 67, 69 to 74, 81, 82, 84, 88, 89, 90, taken from his "Hygiene and Public Health."

H. R. K.

University College, W.C.

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ERRATA.

Page 49, line 30, *for* "Organic pollution," *read* "Some forms of animal organic pollution—as by urine."

Page 60, line 1, *for* "liberated," *read* "induced to separate."

Page 62, lines 19 and 23, *for* "iodide," *read* "iodine."

Page 63, line 17, *for* "*i.e.*, 1 milligramme of oxygen will be consumed," *read* "containing 1 milligramme of available oxygen."

Page 73, line 30, *for* "7," *read* "0·7."

Page 77, line 10, *for* "the most reliable," *read* "next to the meta-phenylenediamine process the most reliable."

Page 104, the first paragraph refers only to the non-poisonous metals.

Page 120, line 18, *for* "would also be precipitated," *read* "would also be, in part, precipitated."

Page 319, line 3, *for* "alum," *read* "alumina."

Page 323, line 28, *for* "alum," *read* "alumina."

Page 324, lines 1, 7, 9 and 11, *for* "alum," *read* "alumina."

Page 352, line 22, and page 396, line 4, *for* "crystallized," *read* "crystallizable."

PUBLIC HEALTH LABORATORY WORK.

PART I.

THE HYGIENIC ANALYSIS OF WATER.

The object of a hygienic analysis of any water is, to learn whether the use of such for drinking purposes should be sanctioned or condemned from a health stand-point.

CHAPTER I.

If it is desired to fit up a laboratory to meet all the requirements of a hygienic analysis of water, it will be necessary to provide in the first place a bench, at least six feet long and two feet broad, standing to half the height of the operator, and placed in a good light; this must be fitted up at the back with shelves, to carry some at least of the chemical reagents, *i.e.*, those which are in most common use. By the side of the bench there should be a tap (furnishing a good supply of pure water), with, if possible, a small water sink beneath it. There must be gas in the room, but not necessarily near the bench, for it can be readily conducted thereto by tubing. A Bunsen gas burner is required, and it is

very desirable to have two of these, so that both can be utilised at the same time. The Bunsen burner (fig. 1) consists of a larger external tube surrounding a smaller gas-delivering one at its base, the former being perforated for the admittance of air—so that at the top the gas escapes well mixed with air, and hence oxidation (and therefore heat) in the flame is increased.

The apparatus required :—

1. A pair of balances with weights. Oertling's No. 3 (Townson and Mercer's Catalogue) will be found to be extremely suitable to all purposes. As shown in the accompanying diagram, they consist of a twelve inch

Fig. 1.—The Bunsen burner.

beam which supports two pans, the ends of the beam being constructed with straight knife edges upon which the pans are suspended by agate planes. The case is fitted with a sliding window in front, which can be closed and still admit of the scales being made to register by means of a screw which projects externally.

The operation of weighing consists of first lifting the beam off its support by means of the screw, and then noting by the long indicator which hangs down in front of the central vertical support of the balances—and which must come to rest in an absolutely central and vertical position—whether the two pans exactly coun-

terbalance each other; if not the balance must be adjusted by means of a small mechanism situated on the top of the centre of the cross-beam and which can be moved horizontally to the right or left according as it is necessary to increase the weight in either of these directions.

The material is then placed upon the tray to the left, and the weights are added to the tray on the right.

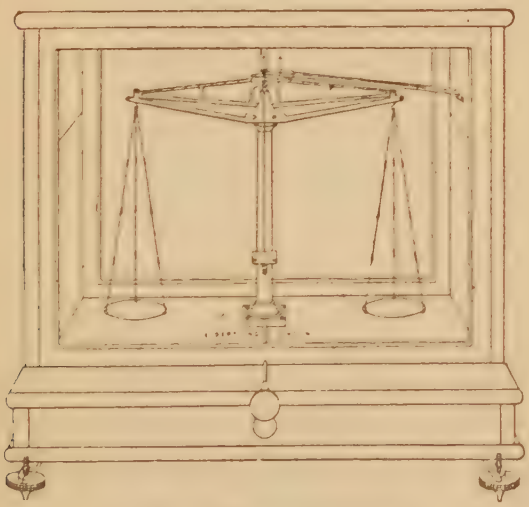


FIG. 2.—Chemical balances.

After the addition of each successive accretion of weight the result must of course be tested, but before any further addition or removal is made the scales must be brought to rest upon their supports, or the apparatus may be put out of gear.

Each of the weights is marked, as the plan of the

box will best show (fig. 4). The larger brass weights representing grammes, the next in size decigrammes, the next centigrammes, and small forceps are used for picking up and applying them to the pan. The milligrammes are added by a little piece of bent wire, which is carried by means of a sliding rod moving just above

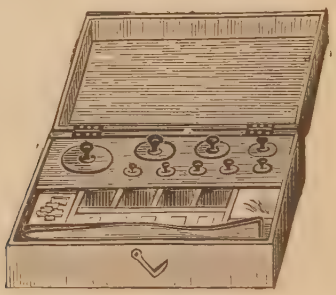


FIG. 3.—Box of chemical weights.

the level of one of the cross-beams, which latter will be observed to show ten markings numbered from one to ten. By sliding the rod which supports the bent wire up to, say the marking No. 5, and then turning it

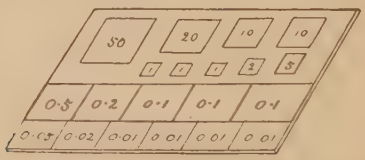


FIG. 4.—Plan showing the arrangement of the weights in box.

round by means of a screw, the wire may be made to ride upon that number, and the carrier can subsequently be withdrawn; five milligrammes of weight will then have been added to that side of the scales.

Example.—A small platinum dish is placed on that pan which is not surmounted by the apparatus for applying milligramme weights.

A five gramme weight is placed on the other pan.

The pans are lifted by means of the screw, and the platinum dish is found to weigh down the five grammes.

The scales are put at rest and a two gramme weight is added to the five, and this is also carried up by the superior weight of the platinum dish.

Another one grm. is added, and this is found to be too much, and is therefore removed, and a five decigramme weight (*i.e.*, $\frac{1}{2}$ grm.) substituted.

The platinum dish is still slightly the heavier, therefore another decigramme is added, with the result that the weights now slightly overbalance the dish.

The one decigramme weight is therefore removed and five centigramme substituted—not enough!

A two centigramme weight further added, however, so extremely nearly establishes the required equilibrium that the addition of another centigramme over-reaches the mark.

Three milligrammes are ultimately found necessary to effect such an uniformity between the weights of the contents of the two pans, that the index rests absolutely in a central and vertical position.

The weight therefore of the platinum dish is:—

Seven grammes	=	7
Five decigrammes	=	0·5
Seven centigrammes	=	0·07
Three milligrammes	=	0·003
Total	=	7·573 grammes.

2. A platinum dish, capable of holding a little over 100 c.c. of water.

3. Two shallow porcelain evaporating dishes, holding a little over 250 and 500 c.c. respectively (fig. 5).

4. A porcelain crucible with cover, for igniting residues (fig. 6).

5. A white porcelain slab, about six inches by four.

6. Two white porcelain basins of about five inches diameter (fig. 7).

Fig. 5.—Evaporating dish.

Fig. 6.—Crucible with lid.

7. A mortar and pestle (fig. 8).

8. Graham's or Liebig's condenser. Graham's will be found a most convenient instrument. As seen by figure 25, it consists of a smaller glass tube bent at one end, where it carries an indiarubber cork. Surrounding this smaller tube for about three-fourths of its extent is a larger one, closed at both ends by indiarubber corks, the centres of which are perforated for the

Fig. 7.—Porcelain dish.

Fig. 8.—Pestle and mortar.

passage of the smaller tube. Cold water is made to circulate constantly in this outer tube by means of the tubing which connects its interior with the tap, the water escaping at the opposite end through the tubing which conducts to the sink. The cool water thus constantly kept circulating condenses the

vapour in the inner tube, at the further extremity of which the condensed vapour finds its outlet and is collected.

A condensing apparatus can be readily improvised, but since either Graham's or Liebig's instruments are cheap (involving the outlay of only a few shillings!) and at the same time are less liable to leak, yield impurities, or to get out of repair, it is better and cheaper to purchase one of these.

9. A set ("nest") of glass beakers (fig. 9) and large watch glass covers for same.

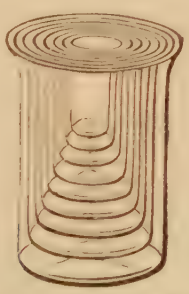


FIG. 9.—Nest of beakers.

10. A bell glass cover.

11. Two boiling-flasks or retorts (of about a litre capacity), one of which is seen attached to the condenser in figure 25.

12. Glass stirring-rods.

13. A small glass-stoppered bottle (250 c.c.) for the soap test.

14. Glass funnels for filtration, with wooden support (fig. 10).

15. Glass burettes holding ten cubic centimetres, and graduated in c.c's., and one-tenth of c.c's., one of which should be mounted upon a wooden stand and should

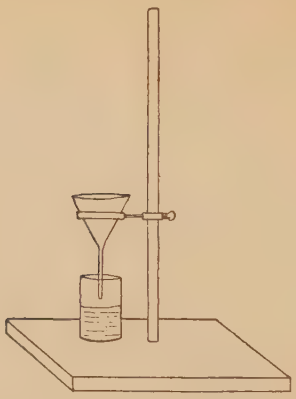


FIG. 10.—Filtering apparatus.

be stoppered at the top, and fitted with a stop-cock at the bottom (fig. 11).

FIG. 11.—Graduated burette with stopcock.

16. Four graduated glass-flasks ("measuring flasks") marked respectively at the height to which 1, $\frac{1}{2}$, $\frac{1}{4}$ and

FIG. 12.—Measuring flask.

$\frac{1}{10}$ of a litre of water will stand. Figure 12 shows one such flask.

17. Six Nessler glasses, four of which are shown in figure 25.

18. A dozen test-tubes, with stand for same, and a test-tube cleaner and holder (fig. 13).

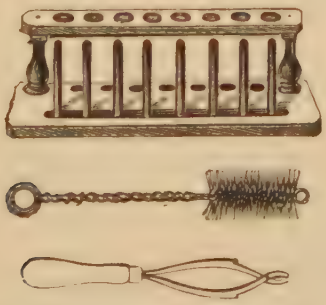


FIG. 13.—Test-tube stand, cleaner, and holder.

19. A glass pipette.
20. Two four-footed iron stands.
21. Two iron tripods (fig. 14).
22. Triangles of iron-wire lined with pipe-clay (fig. 15).
23. Wire gauze, cut about four inches square.

24. A pair of small crucible tongs (fig. 16).

25. A small copper water bath, of about six inches diameter, and fitted with rings, which adapt its mouth

Fig. 14.—Iron tripod.

Fig. 15.

so as to fit different sized evaporating dishes (fig. 17); or the water-bath recommended by the writer, which

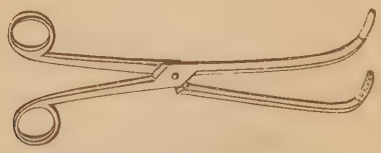


Fig. 16.—Crucible tongs.

comes in equally serviceable for other analyses—apart from that of water. This consists, as in figure 18, of a

Fig. 17.—Ring water bath.

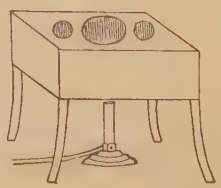


Fig. 18.—The form of water-bath recommended.

water bath of the common shape, but in its roof are *three* openings, a large central and two small lateral ones.

A water bath is a receptacle in which the water it holds may be heated up to a certain temperature; when vessels containing liquids are made to stand in or over the water thus heated, evaporation of their fluid contents may be effected at a temperature which must in any case be considerably below that which would be reached by the application of the naked flame.

26. A water oven. This is a small chamber whose double walls enclose water, which is made to regulate its internal temperature. The residue procured from the evaporation of a liquid over the water bath will still

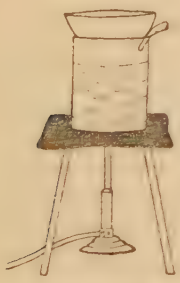


FIG. 19.—A water-bath improvised from an ordinary beaker.

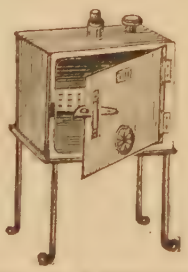


FIG. 20.—A water oven.

contain a trace of moisture, it is therefore subsequently transferred to the oven, where *absolute* drying can be effected (fig. 20).

27. A packet of Swedish filter papers.

28. A long tube of thin colourless glass, known as "the two foot tube," employed in judging some of the physical characters of water.

29. A box of test papers, red and blue litmus and lead papers.

30. A long thermometer graduated in Fahrenheit degrees.

31. Indiarubber corks (perforated and imperforated) to fit the boiling flasks.

32. A "desiccator." A desiccator is simply a glass shade inside of which there is a vessel containing some

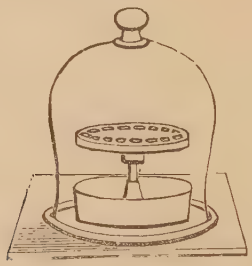


FIG. 21.—A desiccator.

agent which will keep the air free from moisture (such as strong sulphuric acid). A residue completely dried by heat will otherwise absorb a little of the vapour from the atmosphere while cooling, and thus increase *slightly* in weight (fig. 21).

FIG. 22.—A conical sediment glass.

33. A conical sediment glass (fig. 22).

The reagents required consist of:—

1. Distilled water.
2. Distilled ammonia-free water.

3. *Standard solutions* of:—

Chloride of ammonium.
Nitrate of silver.
Soap.
Nitrite of potassium.
Calcium carbonate.
Permanganate of potassium.
Sulphate of copper.
Sulphate of zinc.
Acetate of lead.
Protosulphate of iron.
Iodide of potassium.
Starch.
Hyposulphite of sodium.

Solutions of:—

Alkaline permanganate.
Pure and dilute sulphuric, nitric, and hydrochloric acids.
Liquor ammoniæ.
Chloride of ammonium.
Oxalate of ammonia.
Ammonium sulphide.
Ammonium molybdate.
Sulphuretted hydrogen.
Silver nitrate.
Meta-phenylene-diamine.
Caustic potash.
Potassium chromate.
Potassium iodide.
Potassium ferrocyanide.
Potassium ferricyanide.
Pure soda.
Sodium phosphate.
Nitro-prusside of sodium.
Chloride of barium.
Brucine.
Starch.
Perchloride of mercury.
Nessler's reagent.

4. Zinc foil and copper-turnings.

The Weights and Measures upon the Metrical System.

(A knowledge of which is necessary for water analysis).

Length.

The metrical system is founded upon the "metre" which is divided and multiplied by ten to represent different measures as follows:—

1 millimetre = $\frac{1}{1000}$ part of a metre.
1 centimetre = $\frac{1}{100}$,, ,,
1 decimetre = $\frac{1}{10}$,, ,,
1 metre = 39·37 inches.
1 decametre = 10 metres.
1 hectometre = 100 ,,
1 kilometre* = 1000 ,,

Capacity.

1 centimetre cubed = 0·061 cubic inches.
28·35 ,, ,, = 1 fluid ounce.
1000 ,, ,, or 1 cubic decimetre = 1 litre.
1000 litres = 1 cubic metre.

Weight.

1 cubic centimetre of distilled water at 4° C., and 760 millimetres barometric pressure, weighs 1 *gramme*, which is the standard of weight.

1 milligramme = $\frac{1}{1000}$ part of a gramme.
1 centigramme = $\frac{1}{100}$,, ,,
1 decigramme = $\frac{1}{10}$,, ,,

* The Latin prefix therefore indicates division, the Greek multiplication.

1 gramme = 15·432 grains.
1 decagramme = 10 grammes.
1 hectogramme = 100 ,,
1 kilogramme = 1000 ,,
1lb avoirdupois = 453·5 ,,
1 gallon of water = 70,000 grains.

The term "septem" is sometimes used. It simply implies *7 grains*.

Thermometer Scales.

Centigrade Freezing point = 0 Boiling point = 100
Réaumur ,, ,, = 0 ,, ,, = 80
Fahrenheit ,, ,, = 32 ,, ,, = 212

$$\therefore \frac{Centigrade}{5} = \frac{Réaumur}{4} = \frac{Fahrenheit - 32.}{9}$$

∴ To convert Centigrade to Fahr. × 9 ÷ 5 and add 32.
,, ,, Fahr. to Centigrade subtract 32 and ÷ 9 × 5.
,, ,, Réaumur to Fahr. ÷ 4 × 9 and add 32.

TABLE OF ATOMIC WEIGHTS.

Barium	(Ba)	=	137
Calcium	(Ca)	=	40
Chlorine	(Cl)	=	35·5
Copper	(Cu)	=	63·4
Iron	(Fe)	=	56
Lead	(Pb)	=	207
Magnesium	(Mg)	=	24
Hydrogen	(H)	=	1
Nitrogen	(N)	=	14
Oxygen	(O)	=	16
Sodium	(Na)	=	23
Sulphur	(S)	=	32
Zinc	(Zn)	=	65

Table of Solubilities.

(Showing the salts which are soluble in cold water).

Chlorides.—Nearly all. Those of Bi, Sn and Sb are only partially so (Pb chloride is soluble only in hot water).

Chlorates.—All.

Iodides.—Nearly all. Pb iodide only in hot water.

Sulphides.—Those of the alkalies and alkaline earths.

Sulphates.—Nearly all. Ag and Hg sparingly so.

Nitrates and Nitrites.—All (a few basic nitrates sparingly so).

Phosphates.—Those of the alkalies.

Carbonates.—The alkaline ones.

Silicates.—Those of Na and K.

Arseniates.—Those of the alkalies.

Chromates.—Nearly all (exceptions = Pb, Ag, Hg, Ba and Bi chromates).

CHAPTER II.

A Water Report.

For hygienic purposes such a report must include all the information which can be obtained regarding the extent to which organic matter at present exists; the evidence of former pollution by this material in the oxidised, &c., products of its decomposition; and the amount to which poisonous metals—if any—are present.

Much unnecessary confusion is created by the fact that no fixed terms are recognised and adopted by which results may be *universally* expressed. The results in the several steps of the analysis are, in consequence, variously returned by different analysts in terms of:—

Parts per 100.
Grains per gallon.
Parts per 100,000
Parts per 1,000,000.
Parts per 100,000,000.

It seems most desirable, therefore, that some decision should be come to upon this point. Undoubtedly the best amount for working purposes in many of the stages of the analysis is 100 c.c. of the water, and the result, if this quantity be taken, can generally be at once expressed in "parts per 100,000" (since 100 c.c = 100,000 milligrammes): this is by far the most common term employed in this country, and it is moreover

in general use in France and Germany. In the estimation of organic matter, however, it seems preferable—dealing as we are with such small amounts—in order that the results shall represent whole numbers, to take larger quantities of the water, and to return the estimations as parts per hundred million. The findings of the whole analysis will then be appropriately expressed in terms of either parts per hundred thousand or parts per hundred million.

It appears advisable, nevertheless, to make one exception in the case of a quantitative examination of the poisonous metals, and to express these—in those uncommon cases where they exist—in terms of *grains per gallon*, since they are almost invariably thus referred to in this country.

Such then will be the quantitative expressions used throughout this book. Where, however, the terms employed are other than those to which the reader has grown familiar, he should convert them into such before attempting to form an opinion of the water. The process is a very simple one! Parts per million are obviously converted into parts per 100 million by multiplying by 100, or by moving a decimal point two places to the right, and parts per hundred thousand are converted into parts per million by multiplying by ten; but the conversion of grains per gallon to parts per 100,000 is not so apparent.

Supposing a report reads "chlorine 2·8 grs. per gallon," how many parts per 100,000 will this represent?

Now there are 70,000 grains in a gallon.

$\therefore$ „ „ 2·8 grains in 70,000 grains, or 2·8 parts per 70,000 parts.

$\therefore$ as 70,000 : 100,000 : : 2·8 : x (parts per 100,000).

Or as 7 : 10 : : 2·8 : $x = 4$ (parts per 100,000).

It is thus seen that it is only necessary to multiply results returned in "grains per gallon" by 10 and to divide by 7, in order to convert them into "parts per 100,000," since grains per gallon are parts per 70,000. The converse of this also applies of course, and if it be desired to convert "parts per 100,000" to "grains per gallon" the returns must be multiplied by 7 and divided by 10.

Where the results of a quantitative test—as in the case of poisonous metals—are to be returned in terms of "grains per gallon" it is convenient to measure out 70 c.c. of the sample and to work with this. The reason for this is, that 70 c.c. represent "a miniature gallon" so-called, and the results can at once be expressed in terms of an imperial gallon. The relation between the so-called "miniature gallon" and the imperial gallon depend upon the following facts:—

1 c.c. of water weighs one gramme.

Therefore 70 c.c. ("in the miniature gallon") of water weighs 70 grammes or 70,000 milligrammes.

But 1 gallon of water weighs 70,000 grains.

Therefore since there are 70,000 component parts in either case (of milligrammes in one and grains in the other), the 70,000 milligrammes may be taken to represent "a miniature gallon," in which the grains of the imperial measure are represented by these milligrammes. The results arrived at in milligrammes, where 70 c.c. of water are taken, can therefore be at once expressed in terms of "grains per gallon." Thus it is seen that no calculation becomes necessary, and where the results are expressed in "grains per gallon" the "miniature gallon" may be advantageously chosen.

Subjoined is a copy of the Report in use at the Hygienic Laboratory, University College.

The Hygienic Laboratory,
University College, W.C.

Report on analysis of sample of water received on from

Name or number of Sample	
Date of Collection	
Physical Characters	
Reaction	
Saline (or "Free") Ammonia	Parts per hundred million.
Organic (or "Albuminoid") Ammonia	
Oxygen absorbed from Permanganate in one hour at 80° F.	
Total solid matters	Parts per hundred thousand.
(*a*) Volatile	
(*b*) Fixed	
(*c*) Appearance on ignition	
Total Hardness	
(*a*) Temporary	
(*b*) Permanent	
Chlorine	
Equivalent to common salt	
Nitrogen as Nitrates and Nitrites	
Poisonous metals	Grains per gallon.
Microscopical Examination of the Sediment	

Remarks

Date of examination. Signed

CHAPTER III.

The Collection of Samples.

Since the analyst will be frequently asked for instructions concerning the mode of collecting a sample of drinking water for analysis, it will be opportune to consider at the outset a few points under this head.

At first sight it appears that the matter may be dismissed off-hand by a simple statement to the effect, that such water should always be collected for analysis under exactly those circumstances regarding which it is ordinarily obtained for drinking purposes, and such is broadly correct. It is obvious, since our object is to discover the possibilities of danger in addition to actual danger present, we should not effect this by collecting the water under circumstances which would show the *least* amount of dangerous pollution; but rather, on the other hand, an endeavour should be made to ascertain the *maximum* amount of pollution to which the water is liable, in order that this may be taken as a gauge of its *potentialities* for evil. The "average" sample of water which is often recommended—probably in a spirit of fairness to the water—is neither fair therefore to its consumers, or consistent with the cause of preventative medicine. Instead then—if the collection be made from a house tap—of allowing the water to run for some time before taking the sample, it should be a safer and better policy—if there is nothing to show that some of the water is always first run off and

discarded by the consumers—to include it in the sample taken. As is well known, the water which has been standing over night in the pipes is very liable to show traces of lead, whereas the rest of the water drawn throughout the day may be quite free from this metal; it might therefore be contended, that in view of these circumstances, the course here recommended is somewhat arbitrary. The contention may be met by urging that the motive for a hygienic examination is to ascertain the *potentialities* for evil of a water; that of all the water used throughout the day that which is drawn the first thing in the morning is most liable to be consumed; and that lead is a poison with wonderful cumulative powers.

In the case of streams, lakes, &c., the entrance of any source of pollution, floating scum, &c., should only be avoided to the same extent as it is by those who come to collect their drinking water, and all the conditions of such collection should be closely imitated in taking the sample.

When there is a general system of water supply an effort must be made to meet the same ends by choosing samples from the street fountains and street mains, rather than from storage, &c., reservoirs, and the reputation of the water supply must rest upon the result of an analysis of such samples. Since, however, impurities may be added in its storage and distribution about the house, it would not be fair in all cases to judge a public supply from the tap water of any particular dwelling.

Following out the principles advocated, with regard to those wells from which the water is removed by pumping, it is advisable to continue the process for some time, but not longer than is commonly

done in the ordinary course of events;—as the last "pumpings" will often yield the greatest evidence of pollution. A very fine estimate of contamination may often be made by collecting samples from the wells and pumps immediately around, and taking the purest of these waters collected as the standard of purity to which the others should attain.

When, however, the fact is borne in mind that the water from a well is so materially influenced both as to quantity and quality by the rainfall, it will be seen how materially samples from the same well may vary in purity according as a long dry period may have preceded the collection, or a heavy rain-downpour which may be the means of conveying to the well water impregnated with surface washings, &c. These facts should always be well weighed in such a case, and a further sample requested at a time when the well has run the maximum risk of pollution.

Water is customarily collected for analysis in a large dark blue or pale green glass-stoppered bottle, called "a Winchester quart,"* which holds, however, about twice the amount which is implied in its name, *i.e.*, about half a gallon. These bottles have become generally adopted because, in addition to holding an amount which meets all the requirements of an analysis (even though it be necessary to repeat some of the tests), they are strongly made and of a convenient shape; but obviously any stout glass bottle of pretty much the same dimensions, fitted with a glass stopper, will serve the same end.

The bottle must be thoroughly cleansed by first well rinsing with a little dilute hydrochloric acid, and then

* Stout wicker covers are made to protect them in transit when sent by parcel post or rail.

well washing in good water until the washings are no longer acid.

The sample is then thus collected and dealt with:—The bottle is first quite filled with the water and then emptied; the sample is taken, and the glass stopper, having been found to fit accurately and tightly, is tied down firmly on to the neck of the bottle, and the knots are protected with sealing wax. A label having been attached, care is taken to keep the sample cool and un-

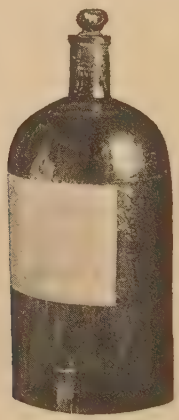


FIG. 23.—The Winchester quart bottle with label affixed.

exposed to light until the analysis is commenced, and under no circumstances should the major part of the analysis be delayed more than 48 hours, or important chemical changes may transpire.

Although information is often furnished, and generally demanded, on all the points bearing upon the possibilities of pollution which the water has incurred, it is often best not to avail oneself of the information

until the analysis is completed, otherwise there is a strong incentive to treat cursorily some part of the analysis, on the supposition that it is unnecessary, which with due care, might have disclosed an undreamt of source of pollution. Regarding such information, the most important to the analyst would be that bearing upon the constitution of the strata through or over which

FIG. 24.—Wicker case for the Winchester quart bottle.

the water has passed, since certain ingredients (in default of such a source) are indicative of organic pollution ; unfortunately this is by far the most difficult information to obtain in a reliable form. Comparatively, all other information is of little worth to the analysis itself, since contamination, past or present, will readily

be detected. It is important, however, to keep in view the fact that our work resides essentially in the cause of disease prevention, and that our duties and responsibilities do not end in returning an analytical report; and that, as sanitarians, all information as regards the risks of pollution are of great value as indicating *possibilities* of danger, when such dangers may not be made manifest at the time in an analysis; it is also of great importance to know, in every instance, the motive for requiring an analysis, as one may often thus learn the presence of some preventable disease in a household, which is not necessarily connected with the water though attributed to it.

It seems hardly necessary to point out that the lesser degrees of pollution are none the less worthy of our consideration because they appear insignificant. A water may effect harm without creating manifest sickness, and many obscure conditions of slightly impaired health and vigour may be due to a *slightly* impure water supply.

Lastly, having found the water polluted, no time should be lost in ascertaining by a thorough examination the *mode* of pollution, in order that efficient remedial measures shall be advised and adopted with the least possible delay.

It is so impossible to form a correct opinion of a sample as to its purity or its potentiality for danger without the knowledge of some of the circumstances of its collection, that it is very desirable that labels should always be given to those collecting samples, and such should be stuck upon the bottle in each case. The subjoined label when filled in would convey all necessary information to the analyst.

SAMPLE OF WATER FOR ANALYSIS.

Reason for desiring an analysis
Date of collection
Where and how collected
(*a*) If from well the depth at which the sample was taken
(*b*) If from tidal river, note whether at the ebb or flood tide
Geological characters of the soil and subsoil of the district
The rainfall during the previous week (*i.e.*, in such terms as "nil" "small" or "great" in amount)
Distance of supply from any evident source of pollution
(*a*) The nature of such source of pollution

The result of every analysis should be carefully entered into a book kept for the purpose, and such a record becomes most valuable for making comparisons with future samples of water from the same sources.

CHAPTER IV.

The Analysis.

It has been said, and truly so, that so small an amount of organic matter as would not call for condemnation in the water, may yet contain the specific germs of disease, and that therefore it is only from the results of a bacteriological combined with a chemical examination, that a water may ever be classified as *safe*. At present, however, there are many difficulties to surmount before most of the specific germs can be identified as such in a water, and in the main a chemical analysis may be held to be very reliable; for it is logical to contend—and experience supports the contention—that organic matter being the food pabulum for specific micro-organisms in water, the probability of their presence should bear a direct ratio to the amount of such organic matter present.

At the very outset it must be realised that in drawing a conclusion as to whether a water is fit for human drink, organic matter (since an analysis mainly aims at detecting this) will give evidence of its presence in most of the steps which form a complete analysis, and that it is this collective evidence which mainly determines a conclusion, rather than the evidence which any one special test may offer. This point is well illustrated in the physical characters of water, for whereas polluted shallow well waters are notoriously often clear, sparkling, and pleasant to the palate (though affording direct

evidence of organic pollution "all along the line" of the analysis), yet these characters are precisely those of our purest and best waters.

For these reasons, and from what follows, it will be seen that evidence of purity or pollution furnished by the senses, is very unreliable in itself, and is not even of much corroborative value. Such tests, therefore, are not worthy of lengthy consideration here.

The Physical Characters.

The sample of water should be well shaken, and then about a litre (1000 c.c.) is emptied into a glass beaker, which is kept covered so as to protect from suspended matters in the air, and after the bulk of any suspended matter which may be present has settled, a thin colourless glass tube twenty-four inches long is filled with the clear (supernatant) water, and from the appearance of this in the "two-foot tube" as it is called the following physical characters are judged:—

1. **Clearness.**—Though the best waters are always bright and clear, these qualities cannot be considered as reliable evidence of purity, for a polluted well-water may possess these characters; and on the other hand any haziness or turbidity—which is of course created by minute particles of suspended matter—may by chemical and microscopical examination be proved either inoccuous or harmful. The degrees of such turbidity may be expressed as "clear," "very slightly turbid," "slightly turbid," and "turbid."

2. **Colour.**—To detect this the tube is held vertically upon a white porcelain slab, and the observer looks down through the depth of the column of water

on to the slab, which forms the background. It is only in this manner that the faintest degrees of colouration are best appreciated, if even they be detected at all; and when thus examined it is rare that the water is not seen to possess some colour, however faint. In a good water it is generally of an extremely faint greyish-blue or greenish tint, and if there is any doubt upon this point another similar tube should always be filled with colourless distilled water, and a comparison made after the two waters have been placed under exactly the same conditions of depth of column and light access, &c.

The various hues of yellow and brown will denote the presence of either animal or vegetable pollution (*i.e.*, sewage or peat), or mineral contamination such as iron or clay (silicate of alumina),—but generally any iron present will have been precipitated to form a sediment of the hydrated ferric oxide (*i.e.*, "rust").

A marked green denotes the presence of the vegetable matter containing chlorophyll, which will generally be found to mainly consist of the harmless unicellular algæ. The water in the neighbourhood of dye-works may be of course variously coloured.

Colour alone is thus seen to afford no justification for condemning a water until the nature of the material creating it is known; peat, for example, present to quite a harmless extent, will often colour a water highly. The importance of the test, *per se*, does not seem to warrant any attempt at definite measurement.

3. **Taste.**—The pleasant taste of good water is created by the gases dissolved in it, but since water must contain large quantities of any ingredient for its presence to be detected by this means, and as an indi-

cation of dangerous contamination, the test is practically useless.

Among the many ingredients to which ordinary drinking water is liable, iron stands alone as offering any valuable indication of its presence, and so little as $\frac{1}{4}$ grain to the gallon of this metal will impart a Chalybeate flavour. Chloride of sodium (common salt) may be present in enormous quantities (75 grains to the gallon) without causing a brackish taste, and waters foully polluted with organic matter are often so palatable that wells, &c., containing them are frequently patronised by the public in preference to those which contain much purer waters.

It is not advisable in every case to taste samples sent for analysis, and the analyst must exercise his discretion from the information which he receives with the sample as to the safety of such a procedure.

4. **Smell.**—This is best detected by placing some of the sample into a glass stoppered bottle (itself odourless), immersing this in hot water at about 140° F. for a few minutes, and then taking prolonged (deep) sniffs at its contents after removing the stopper. For most practical purposes, however, it will suffice if the sample is smelt after it has been thoroughly shaken, and it is only necessary when a suspicion remains after this procedure to resort to the plan of heating the water—except it be in those cases where there is strong reason for considering that odoriferous gases may be present in small quantities inappreciable except by heat, such, for instance, as would arise when the water is judged to have run risk of coal-gas contamination, &c.

The test of smell is unreliable, and none may be evident in waters which are considerably polluted by sewage; it must be borne in mind also that many of

the noxious materials which may gain access to a water have little, if any, smell originally.

Any coal gas, sulphuretted hydrogen, or ammonium sulphide present, would be detected, and more especially if the water is heated to about 120° F.

The variety of odours which may be given off from a water defies description; many of them, though quite peculiar and distinct, it seems quite impossible to describe, and any comparisons made with more familiar smells will only appeal to a certain proportion of those who test them.

Since, however, a good water should contain no smell whatever it seems unnecessary to define an odour when it exists, more especially as it can rarely give any clue as to the nature of the pollution. It is far better that the analyst describes the odour in his own words than that he should be cramped by any desire to confine his returns within the category of any such well-known terms as "musty," "horse-pond-like," "pig-odour," "fishy," and "cucumber-like."

A distinctly putrid odour is characteristic of large quantities of decomposing animal or vegetable matter, and an *urinous* odour is sometimes distinctly perceptible when fresh sewage has gained access to the water. The rotten egg smell of sulphuretted hydrogen and that of coal gas are both peculiar and distinctive. The presence of any of these odours would condemn the water, as indeed should any other if well marked (*vide* "Gases and Vapours in Water").

5. **Æration.**—Evidence of this is afforded by minute air bubbles collecting at the sides and bottom of the tube and rising up occasionally through the water to the surface, and also by the degree of lustre ("sparkling") the water possesses.

It is of no value by itself, in the estimation of the purity or impurity of a water, though a good water to be palatable must be well ærated (*vide* "Gases and Vapours in Water").

6. **Reaction.**—This is important, not so much as affecting an opinion upon the wholesomeness of the water, but from the value the knowledge acquires in some further stages in the analysis, for the correct performance of which it becomes necessary to neutralise any acidity in the sample. Though the most polluted waters from animal organic matter are generally decidedly alkaline from the carbonate of ammonia furnished by urine decomposition, yet most waters will be found to be alkaline in practice, the alkalinity being generally given by calcium carbonate, and less often by sodium carbonate.

It does not appear generally necessary for hygienic purposes to test the *degree* of alkalinity or acidity of the water, apart from that denoted by delicate litmus papers (blue and red).

The estimation of alkalinity is, however, sometimes of value, and it may be best effected in the following manner:—100 c.c. of water are placed in a white porcelain dish, and tinged yellow by a solution of methyl-orange; decinormal hydrochloric acid is then run in from a graduated burette until the appearance of a red tint denotes that the neutral stage has just been reached. The estimation is made in terms of calcium carbonate (to which most of the alkalinity is generally due) and each c.c. of the acid solution required to effect neutralisation is equivalent to 5 milligrammes of this salt.

7. **The sediment.**—The presence of this, together with its macroscopic appearance, should be noted at this stage, but any opinion of its nature must be reserved until a microscopic examination has been made.

CHAPTER V.

Organic Matter in Water.

The hygienic analysis of water essentially aims at attaining two objects, *i.e.*, the detection of the extent of organic pollution, and the detection of the presence of poisonous metals. The former is the more important and urgent of the two, since the evil consequences following in the wake of organic pollution are generally more suddenly dangerous and widespread than those of the latter. By organic pollution is included the fouling of water by both *animal* and *vegetable* material together with the products of their decomposition, and since the relative significance and danger of each of these differs very materially (animal contamination being far more dangerous and harmful than vegetable), it is important, both by a knowledge of the water's source and by chemical analysis, to discover which form of organic matter is fouling the water, or in what proportion they are respectively doing so.

Organic matter gains access to water by manifold channels, many of which will readily occur to the reader, and all of which may be learnt by consulting the best works upon Hygiene and Public Health.

This organic matter, as is well known, has a strong natural tendency to resolve itself under suitable conditions of temperature, air and moisture, into simpler parts, by fermentation, eremacausis and putrefaction. In the process of fermentation numerous minute forms of animal or vegetable life are developed, which if they

do not start the process themselves, play an important part in fostering and continuing it.

By eremacausis is implied the breaking up of organic matter by slow oxidation, in other words the natural "burning off" of organic matter.

Whereas in these two processes no offensive odour is created, when putrefaction sets in odorous gases are evolved, which mostly consist of compounds of sulphur and phosphorus, and—as in fermentation—minute organisms develop, which mainly take the form of the vegetable fungi and the animal infusoria.

The great necessity for a closely proximate estimation of this danger-carrying and danger-breeding material in a water has been recognised for many years, and the difficulty encountered in performing it is both interestingly and instructively exemplified in a perusal of the successive methods to this end which have been advanced and adopted; but the subject must be treated very summarily here.

One method, which was for a long time a popular one, took advantage of the destructibility (and loss) of organic matter by heat. A large bulk of water was evaporated to a solid residue at a low temperature, and this was then heated at a high temperature ("ignited") until all organic matter was burnt off, and nothing but mineral ash remained. The difference in weight of the residue before and after ignition was held to represent the organic matter, until successive chemists pointed out and insisted upon the fact, that the loss by ignition included, in addition to organic matter, some of the mineral constituents as well, and that more especially was this the case with the nitric acid which thus became dissipated. The organic matter therefore was considerably over-estimated by this method, but it had

become a popular favourite, and lived, strange to say, for a long time after the facts which belied its accuracy were generally known and appreciated among chemists.

The effort to estimate the organic matter from the amount of oxygen of which it will deprive the permanganate of potassium (Condy's fluid), was practised almost universally for another long period, and it remains as an auxiliary test for organic matter to this day. The facts, however, that potassium permanganate in solution is so very unstable, that it will part with its oxygen more readily to the least dangerous (*i.e.*, vegetable) than to the more dangerous (*i.e.*, animal) pollution, and that the oxidisable organic matter bears an unknown and inconstant ratio to the *total* organic matter,—have all conduced to some dissatisfaction and mistrust of the test, and the outcome has been that further endeavours have been made to find another one more inclusive and reliable in its estimation.

Dr. Frankland has devised a beautiful and ingenious process to meet the want, but it is quite unsuited to the bulk of Health Officers, and there is scope for some error to creep in even with practised hands. He evaporates a measured volume of water to a solid residue, and this is collected in a hard glass combustion tube, mixed with oxide of copper, and burnt in a furnace. The oxide of copper parts with its oxygen to the organic matter, which is completely destroyed, and the carbonic acid and nitrogen which result are collected, measured, and returned in terms of "organic carbon" and "organic nitrogen."

A method superior in its facility of execution, against which no important chemical defects can be raised and sustained, and one which has rapidly become popular and accepted among the bulk of chemists, is that known

as "The Wanklyn, Chapman and Hall Process." By it an endeavour is made, after computing the amount of "saline" ammonia *originally present* in the water, to estimate the amount of nitrogenous organic matter from the amount of ammonia which can be derived from the breaking up of such matter by the addition of a solution of strongly alkaline permanganate of potassium, and then boiling.* No better clue to the presence of organic matter can well be imagined than an estimation based upon the nitrogen produced by its decomposition, but the question which will naturally arise is as to whether *all* injurious organic matter is nitrogenous, and there is no doubt that broadly for the purposes of water pollution it appears to be so; the composition of organic matter, however, is so varied and complex, and defies analysis so successfully, that much has yet to be learnt of its chemical constitution.

Of course great consideration is had in the process to the amount of the "saline" ammonia, and it is held to have *its* origin mainly in organic pollution also, though it does not, like the "organic" ammonia, necessarily indicate such pollution *actually present as organic matter*, but rather an early stage in the decomposition of such matter.

While, therefore, the ammonia which is created by the process must always be considered the greatest index of danger,—since it is derived from organic matter *actually present* at the time of analysis,—the amount of "saline" ammonia is considered of great value as an index in conjunction with this:—for most of it, and very nearly *all* in many cases, must be derived from

* The nitrogen of all nitrogenised bodies (present other than as nitrate or cyanide) comes away as ammonia when boiled with the hydrated alkalies.

extremely recent organic pollution, although very little of the original organic matter itself whose decomposition furnished it, may be present in the water.

It is obvious that no chemical process can determine as to whether the organic matter is living or dead, or whether in the former case it is harmful or not. When it is considered how minute the germs of disease are, it will be seen at once that considerable quantities cannot by themselves materially affect the amount of—say "organic ammonia;" but since they would always be associated with organic food-pabulum, the presence of organic pollution which this would disclose in the analysis, sounds the warning note.

The tests for organic matter, in addition to those which aim at detecting it when actually present, also include others whose object it is to detect the *products of organic decomposition*, *i.e.*, oxidised nitrogen in the form of nitrates and nitrites, and those other chemical constituents which by entering into the composition of organic bodies gain access to the water along with it, *i.e.*, phosphates, sulphates and chlorides.

CHAPTER VI.

Wanklyn's Process.

The principle upon which this process is conducted is that known as a "colorimetric analysis,"—a variety of volumetric analysis, in which a reagent having the power of combining with the substance sought after and creating a colour with it, is added to a measured quantity of the solution under analysis. The amount of the substance present and thus combined, is then found by adding to a similar volume of distilled water and reagent, a solution which contains known quantities of the substance, and this is continuously added until the colour is matched (which act of matching is known as "titrating"). The amount of the substance contained in the amount of the standard solution used, is of course the same as that existing in the solution under analysis.

Apparatus Required.

1. A condensing apparatus.

2. A boiling flask or retort, most conveniently of about a litre capacity. This must be supported upon a four footed iron stand across the top of which a piece of wire gauze has been placed, and then attached to the condensing apparatus by means of the cork which is perforated by the bent end of the smaller tube, the extremity of which is allowed to project about half an inch below the cork into the neck of the bottle (*vide* figure 25).

3. Six Nessler glasses. One of these is represented in figure 25 as catching the condensed vapour. They

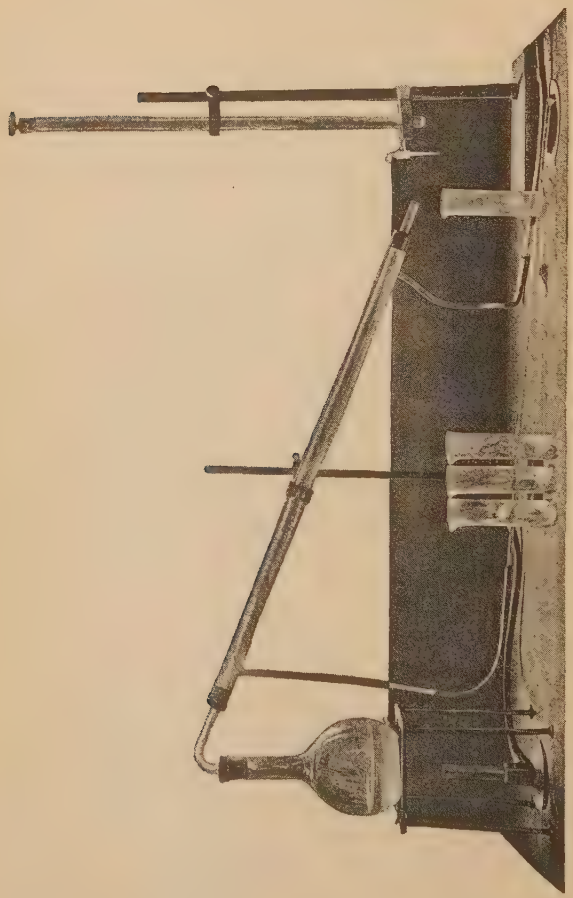


FIG. 25.—The apparatus employed in the estimation of the nitrogenous organic matter by Wanklyn's method.

are each marked off at a point which indicates the level to which 50 c.c. of water will stand in them, and should

be made of thin colourless glass and of precisely similar diameter.

4. A white porcelain slab about six inches square, which is used to facilitate colour comparison.

5. A burette graduated in cubic centimetres and tenths of cubic centimetres, fixed upon a stand and fitted with a glass stop-cock which regulates the delivery with delicacy.

6. A glass measuring flask for 500 cubic centimetres (500 c.c.) of water.

Chemical Reagents.

1. A standard solution of chloride of ammonium, made to the strength that 1 c.c. contains 0·01 milligramme of ammonia.

2. Nessler's reagent. This consists of a solution of potassium iodide and the periodide of mercury in distilled ammonia free water, the whole being rendered strongly alkaline with caustic potash. When this reagent is applied to a solution containing ammonia it imparts a colour varying from a faint yellow to a dark brown or amber, and sometimes even a precipitate, according to the amount of ammonia present; and this reaction, which is due to the formation of ammonio-mercuric iodide, may be considered as quite characteristic of ammonia, since it is not shared by any other substance with which we are familiar. It is important, however, to clearly understand the fact that it does not react to *organic matter as such*.

The solution of the reagent should have an extremely faint yellow colour, which indicates that it is saturated with the periodide of mercury, and is therefore "sensitive;" should it be colourless and not "sensitive," this

can be corrected by the addition of a drop or two of a saturated solution of corrosive sublimate.

Any precipitate of the red mercuric iodide which settles should not be disturbed when the reagent is being used.

3. A strongly alkaline solution of the permanganate of potassium which has been boiled for a few minutes (five) in order to get rid of any traces of ammonia, and the loss by evaporation is made up by distilled ammonia free water.

4. Ammonia-free distilled water is made by collecting the distillate from a condensing apparatus (Graham's or Liebig's), after discarding the first quantities which contain any free ammonia (as shown by Nessler's reagent); and care must also be had not to allow the water to boil down too low, or the last amount of distillate may also contain ammonia. For most tap waters, if a litre of such be placed in a boiling flask, it will only be necessary to discard the first 150 c.c., of distillate and to stop the process of distillation when about the same amount remains behind in the flask, all then collected will be "ammonia-free."

The Process.

Firstly the amount of "free and saline ammonia" is calculated; the latter term including that which exists in solution in the water, in combination with acids (carbonic, nitric, &c.), or any which may exist in some other easily decomposable form.

1. The sample of water having been well shaken, 500 c.c. of it (*i.e.*, half a litre) are measured out and placed within the boiling flask.

2. If the water is acid, or even neutral, a little pure

anhydrous sodium carbonate should be added so as to insure alkalinity. The motive for this is primarily to enable the free ammonia to come away readily, since acidity exerts a fixing influence upon it, and secondarily it will prevent, in a measure, the caking of the solids which takes place in the flask by the end of the process, and which entails trouble in removal.

3. The boiling flask is then tightly connected by the cork with the Graham's condenser,—*tightly* in order that uncondensed vapour shall not escape at this point. The Bunsen burner is next lighted, the flame applied to the flask, and *rapid* boiling is encouraged,—care being had that "spurting" does not take place.

4. The water tap is turned to such an extent that the water after circulating in the outer tube returns in a small stream to the waste-sink.

5. A Nessler-glass is placed so as to catch the distillate, and when sufficient of this is collected so as to reach up to the level of the 50 c.c. mark, a second glass is substituted, and then a third.

6. When three Nessler glasses are thus filled up to their 50 c.c. marks, a fourth is placed to catch the distillate, while 2 c.c. of Nessler's reagent are added to each of the three glasses. If these glasses be disposed upon the white porcelain slab from left to right in the order in which they receive the distillate, the colour created in each of them by the reagent will show a decrease in amount from left to right, since the first 50 c.c. collected will contain the most "free ammonia" and the third the least.

7. The gas may be turned out, and the distillation stopped, if there is no colour created in the third Nessler glass, or if it be *extremely* faint,—since all the "free and saline ammonia" will then have come over. If, how-

ever, the colour is at all *marked* in the last Nessler glass a fourth must be collected and tested with 2 c.c. of the reagent; and even a fifth may be necessary in very rare cases. It is absolutely imperative that *all* the "free and saline ammonia" in the original 500 c.c. of water shall be removed, and it is rare in a drinking water that the 150 c.c. of distillate does not contain the whole of this.

8. The presence and degree of coloration must always be judged by looking down through the depth of the water on to the white slab, and precaution must be taken that the bottoms of the glasses, and the upper surface of the slab also, are perfectly dry, as a thin layer of water intervening between these diminishes materially the depth of colour, and thus leads to error in making a comparison.

9. The colour in the glasses is caused by the presence of ammonia, the amount of which we do not know however, and the knowledge is acquired in the following manner:—Fill another Nessler glass nearly up to the 50 c.c. mark with distilled ammonia free water, add 2 c.c. of Nessler's reagent to it, and then ascertain how much of a standard solution of ammonia of known strength, (*i.e.*, the standard solution of the chloride of ammonium), has to be added to this water to match the amount of coloration in each of the three Nessler glasses. The amount of ammonia thus required must then be that in the glass with which we are making the comparison, for equal tints of colour are created by similar amounts of ammonia.

10. It is found that it is not necessary to match each glass respectively, since three quarters of the total amount of "free and saline ammonia" are constantly contained in the first glass of distillate; that is to say, this ammonia comes off so remarkably readily and

evenly that on this account it is only necessary to compute the amount which the first Nessler glass contains, since this will constantly represent three quarters of the total.

11. Drop, therefore, into the comparison test-glass containing the distilled ammonia-free water and Nessler reagent, the standard solution of ammonia chloride, in half c.c's. from the burette, and when after gently shaking up or stirring with a clean glass rod the colour is found to be approaching that in the first Nessler glass, wait about three minutes before adding further, since the colour deepens a little upon standing.

12. Having thus effected a colour match by placing the two glasses side by side upon the white slab under exactly the same conditions of light access and by comparing the colours from above, the amount of ammonium chloride solution which has been used to effect this is read off, and the ammonia which this is equivalent to will be the amount of the "free and saline ammonia" in the first Nessler glass. The quantity thus estimated will represent three quarters of the total amount, and another quarter will still be required to match the colour in the other two glasses.

Example.—150 c.c. of distillate have been collected, the reagent added, and the last 50 c.c. distilled is found to contain no trace of ammonia. The whole of the "free and saline ammonia" in the 500 c.c. of water has therefore been collected.

It was necessary to add 3 c.c. of the standard solution of ammonium chloride to the contents of the comparison test-glass, in order to match the colour in the glass containing the first 50 c.c. of distillate.

But the colour in this glass is created by three-quarters of the total "free and saline ammonia," so

however much this represents, one-third of it has yet to be added to get the total. Supposing in this instance 3 c.c. of the standard solution of ammonium chloride are required to match the colour created by three-quarters of this total ammonia, then let x represent the amount required for the whole; 3 c.c. will then be equal to $\frac{3}{4}x$, or $x = \frac{4 \times 3}{3} = 4$ c.c.

The total amount then of "free and saline ammonia" in the 500 c.c. of water corresponds to the ammonia present in 4 c.c. of the standard solution.

But 1 c.c. of this standard solution contains 0·01 milligramme of ammonia.

∴ 4 c.c. of this standard solution contains 0·04 milligramme of ammonia.

∴ there is 0·04 milligramme of "free and saline ammonia" in the 500 c.c. of water.

It is customary to express the results of this process—dealing as we are with such small quantities—in terms of "parts per million or parts per hundred million."

We must therefore convert the cubic centimetres of water into milligrammes likewise, and since 1 c.c. of water weighs 1 gramme, and 1 gramme contains 1000 milligrammes, 500 c.c. of water will represent 500,000 milligrammes.

∴ there is 0·04 milligramme of "free and saline ammonia" in 500,000 milligrammes of water,

Or × 2 = 0·08 part of "free and saline ammonia" in 1,000,000 parts of water,

Or × 100 = 8 parts per 100,000,000.

Conclusions to be drawn from the amount estimated.—If the "free and saline ammonia" exceeds 0·08 part per million or 8 parts per hundred million, it almost invariably proceeds from the fermentation of urea into

ammonium carbonate, and it indicates comparatively recent urine pollution; but since the amount of the "albuminoid ammonia" must be considered along with that of the "free and saline" in drawing general conclusions, further remarks under this heading are deferred until this estimation has been made.

The next step in the process is to continue the distillation more slowly after adding 50 c.c. of the alkaline permanganate of potassium solution to the water left in the boiling flask; to collect the distillate in three Nessler glasses: and to repeat the process of "Nesslerising" precisely as before. The ammonia estimated is here, however, called "albuminoid ammonia," since it is derived from the breaking up of albuminoid and other nitrogenous organic matter by means of the alkaline permanganate at the boiling temperature. It is important to remember, that in this case the ammonia comes over more slowly and much less evenly (the second Nessler glass sometimes containing as much as the first), so that grave errors (of under estimation) may be made by considering the first 50 c.c. of distillate to contain three-quarters of the total "*albuminoid ammonia*." The colour, on this account, in each Nessler, must be matched separately, and it is convenient to commence with the glass containing the least colour, so that having made a match, it is only necessary to add more of the standard solution to increase the colour already created in order to match the next deepest colour, and so on; otherwise a fresh test solution would have to be made for each comparison and much time and reagents wasted. Of course distillation must be continued, as in the former case, until *all* the "albuminoid ammonia" has been brought over.

Example.—It was necessary to distil over 200 c.c. in four

Nessler glasses before all the ammonia had come over.

The fourth glass had colour equal to that created by $\frac{1}{2}$ c.c. of the standard solution.

The third glass had colour equal to that created by 1 c.c. of the standard solution (*i.e.*, another $\frac{1}{2}$ c.c. of standard solution had to be added to the comparison test-glass).

The second glass had colour equal to that created by 2 c.c. of the standard solution (*i.e.*, another c.c. had to be added).

The first glass had colour equal to that created by $2\frac{1}{2}$ c.c. of the standard solution (*i.e.*, an extra $\frac{1}{2}$ c.c. of standard solution had to be added).

$\therefore (\frac{1}{2} + 1 + 2 + 2\frac{1}{2}) = 6$ c.c. of standard solution were altogether required to match the colour created by the "albuminoid ammonia" in 500 c.c. of water.

But 1 c.c. of standard solution = 0·01 milligramme of ammonia.

$\therefore$ 6 c.c. of standard solution = 0·06 milligramme of ammonia.

500 c.c. of water = 500,000 milligrammes.

0·06 milligramme of ammonia ("albuminoid") in 500,000 milligrammes of water.

Or 0·12 part of ammonia ("albuminoid" in 1,000,000 parts of water.

Or 12 parts of ammonia ("albuminoid") in 100,000,000 parts of water.

Conclusions to be drawn from the amounts estimated.—Wanklyn's conclusions are generally accepted, *i.e.*, "when the albuminoid ammonia amounts to 0·05 part per million, then the proportion of free ammonia becomes an element in the calculation, but if 0·00 then it may be passed as organically pure despite much free ammonia and chlorides. Free ammonia being very

small, a water should not be condemned unless the albuminoid equals about 0·10."

A water is generally considered just within the border line of safety if the "free" and "albuminoid" ammonia are 0·05 and 0·08 respectively. Much "albuminoid" along with a small amount of "free" ammonia indicates vegetable contamination, and this indication gains further support if there is only a faint trace of chlorides and no excess of nitrates and nitrites. Much "free," and excess of chlorine, nitrates and nitrites, will denote animal pollution, though in those rare cases where a water is solely polluted by effluvia (arising from animal matter) there may be no excess of chlorine present.

Excess of "free" ammonia, unaccompanied by any excess of "albuminoid" may be due to the following circumstances :—

(*a*). The sample is rain water, which always contain ammonia and sometimes in large amounts.

(*b*). The water has percolated strata in which some ammonia salt is present.

(*c*). The water has percolated a stratum containing a reducing agent (generally an iron salt) which has decomposed nitrates and nitrites originally taken up by the water from other strata previously permeated, as in the case of some deep well waters; or pipes, &c., with which the water comes in contact, may effect this reduction,—as in the case of artesian well waters, in which "free" ammonia is always present.

(*d*). Organic pollution.

The necessity of considering the amount of "free ammonia" when in excess, *along with that of the "albuminoid,"* rather than judging it alone as indicative of danger, is best exemplified in the case of rain-

water, in which "free ammonia" often exists in considerable quantities and especially when collected in town districts,—where it is derived from the soot in the atmosphere. In the rain collected in open country districts, however, faint traces of ammonia are always found, and some of it is combined with nitric acid—formed when electric discharges pervade the atmosphere—and it is held that this electrically produced nitrate of ammonia is the origin of all organic nitrogen. The further steps of the analysis will always indicate the source of any excess of "free ammonia," whatever this may be, and where it is derived from organic pollution the "albuminoid ammonia" denotes the fact by being also in excessive quantities.

Notes upon the Process.

The Nessler reagent will create the *faintest possible* evidence of a yellow colour in water not containing a suspicious amount of "free ammonia," when this is examined in a Nessler glass; if, however, this colour is distinctly apparent the water is a very suspicious one. This forms a rough and reliable test of the freedom of a water from an excessive amount of "free ammonia," and to a great extent of its purity, but it must be borne in mind that slight excess does not necessarily imply animal pollution, and a water may contain such matter recently acquired and yet show but little "free ammonia." A water which shows a marked amber tint with Nessler reagent must of necessity be exceedingly foul.

Where by Wanklyn's process ammonia is present in the sample in large quantities, the amount of coloura-

tion to be matched is in consequence great in degree, and it will frequently be found that as the standard solution is added to the comparison test-glass, a turbidity appears, which by altering the nature of the colour as well as its depth of tint, makes the process of comparison (or "Nesslerising" as it is termed) a very difficult and unreliable one. In these cases the comparison test solution should be discarded and a fresh one made, and if say a couple of c.c. of the standard solution be run into the test-glass *before* the Nessler reagent is applied, it will have the effect of materially lessening the turbidity or precipitate, if not of entirely preventing it.

Where the process is applied to extremely foul waters, or to sewage effluents, the degree of colour due to the ammonia in the first 50 c.c. will be so intense that it will be impossible to match it with the standard solution, and in most cases a copious precipitate will appear and prevent further comparison. In these cases therefore, the distillate should be diluted with an equal bulk, and sometimes even with three or five-fold its amount, of distilled ammonia free water, and when the estimation is effected at the end of the process allowance must be made for this dilution. I have, therefore, made it a practice, if when the Nessler reagent is added a distinct amber tint appears, to consider the distillate too rich in ammonia to estimate without dilution, and thus save time and trouble.

A little practice makes the colour comparison an easy matter, and experience will enable the operator to guess the approximate amount of standard solution required to make the match, and to effect this with great rapidity. Although instruments and other means have been suggested to facilitate this end, such are of no value

whatever, even to the merest novice in chemical proceedings.

Strange to say, though the urea is decomposed in the process of boiling with the alkaline permanganate, its decomposition does not yield any ammonia, and this at first sight would seem a grave defect in the process. Whenever, however, it is considered that this is, so far as has yet been shown, the only nitrogenous organic contamination to which a water is liable which does not under the circumstances yield ammonia, and that the urea in the urine almost as soon as it enters the water becomes changed to carbonate of ammonia, and as such is detected in the saline ammonia,—the matter is not one of great moment. Moreover, it is not necessary that in the process the *total* nitrogen contained in organic matter should be evolved as ammonia, so long as that which *is* evolved gives an index which bears a pretty fixed and constant ratio to the total amount; so that from this index an empirical standard of purity can be formed. The process appears to efficiently meet this requirement.

Sometimes while extracting the "albuminoid ammonia" the contents of the boiling flask boil too violently and "bumping" ensues; to obviate this a gentle shaking of the flask will often suffice, but in default of this a few fragments of freshly ignited tobacco pipe (as suggested by Mr. Duppa) afford an excellent remedy. The foulest waters, and those containing much saline matter, are apt to bump most, and it is highly important to prevent this, since uncondensed vapour thereby escapes at the distal end of the tube, and sometimes some of the water from the boiling flask,—both of which occurrences obviously vitiating the results; and when some of the water to which the alkaline permanganate has been

added thus spurts over into the Nessler glass placed to collect the distillate, it is of course impossible then to "Nesslerise," since the distillate has a pink colour. There is no alternative then but to commence the process all over again with a fresh quantity of the sample.

All the materials used must be scrupulously clean, and if the condenser has not been used quite recently for the same process or for distilling ammonia free water, it is advisable to distil a little such water through, to ensure the absence of ammonia in the apparatus; care must also be had that no ammonia fumes are escaping—or have recently done so—into the atmosphere of the room from the bottles containing ammonia solutions.

FIG. 26.—A burette filled up to the 10 c.c. mark.

The boiling flask if showing any fur from a previous analysis should be cleansed with a little dilute hydrochloric acid, and then washed with pure water until the washings are no longer acid.

In judging of the height to which fluid stands in a burette always take the level of the convex lower border of the meniscus which forms upon its upper surface, and make this rest upon the line to which the fluid is required to reach. Water standing to the level of 10 c.c. in a burette will appear, therefore, as in the accompanying figure (26).

When the "albuminoid ammonia" comes over so

evenly and slowly that almost all the water in the retort threatens to be used up, and in those rare cases where "the free ammonia" seems to hang about in small quantities, it is a good plan to adopt the measure (Rich) of "Nesslerising" the first 50 c.c., and to return the rest of the distillate to the flask and redistil it before "Nesslerising."

As Prof. Mallet points out, "the gradual evolution of albuminoid ammonia indicates the presence of organic matter in a fresh or comparatively fresh condition, whilst rapid evolution indicates that the organic matter is in a putrescent or decomposing state."

The distillation adopted in the process adds materially to the delicacy of the operation of estimating the amount of the ammonia, for *inter alia*, it separates the salts which the water contains, thus preventing the turbidity which often arises when Nessler's reagent is added to undistilled water.

Solutions Required for Wanklyn's Process.

Nessler's Reagent is made by "taking 35 grammes of the iodide of potash, 13 grammes of corrosive sublimate, and about 800 c.c. of water. These materials are then heated to boiling and stirred up until the salts dissolve. That having been accomplished, a cold saturated solution of corrosive sublimate in water is cautiously added, until the red periodide of mercury, which is produced as each drop of the solution falls into the liquid, just begins to be permanent. In this manner we obtain the solution of the iodide of potassium saturated with mercury periodide, and it remains to render it sufficiently alkaline and to render it sensitive. This is accomplished

by adding 160 grammes of solid caustic potash, or 120 grammes of caustic soda to the liquid, which is afterwards to be diluted with water, so that the whole volume of the solution may comprise one litre. In order to render the Nessler reagent "sensitive," it is mixed finally with a little more cold saturated solution of corrosive sublimate and allowed to settle" (*Water Analysis*, Wanklyn).

The reagent should be kept in a tight-fitting glass stoppered store bottle, and small quantities emptied out into a smaller one for use from time to time.

The **standard solution of ammonium chloride** is made by dissolving 0·0315 grammes of pure chloride of ammonium in a litre of distilled ammonia-free water.

The amounts recommended to be used in making up the **alkaline permanganate of potash solution** are:—

Caustic potash, 200 grammes.

Permanganate of potash, 8 grammes.

Water, 1 litre.

CHAPTER VII.

The Oxidisable Organic Matter Process.

A certain quantity of any organic matter which may be present in water is always oxidisable, but unfortunately this amount varies with the nature of the organic pollution, and—since it bears no constant ratio its estimation furnishes no reliable index to the total quantity of such pollution present. Moreover, the *oxidisable* matter itself is not even estimated in its entirety by the process, for different substances reduce different proportions of the permanganate employed in the process. In the various attempts to estimate this matter in water advantage is taken of the well known chemical fact, that in the presence of organic material the permanganate of potassium under favourable conditions will part freely with its oxygen, until all the permanganate has become reduced to hydrated manganese dioxide, the first stage being :— $K_2Mn_2O_8 = K_2MnO_4 + MnO_2 + O_2$; and that such change is denoted by the original pink colour which this salt gives to the water being replaced by one of a brownish hue.

The permanganate of potassium is unfortunately in some respects an unsatisfactory salt to work with : it does not, for instance, oxidise albuminous matters, nor does it affect creatin, sugar, gelatine, urea or fatty matters ; and the standard solution of the salt which has to be employed is very unstable, and in consequence unre-

liable unless frequently renewed, and on this account small amounts only must be made at a time.

In the face of these drawbacks, and possessing as we do in Wanklyn's process the means of making a far closer and more reliable estimation, the chief value of the test lies in the direction of its employment as a means of instituting comparisons between the purity of different waters, or of the same water at various times. A great deal of time and care has to be devoted to the process, and liability to error in any but very careful hands is greater than in any other of the processes introduced within these pages. It would have great value as a *rough* test for organic pollution if it had the recommendation of quick accomplishment, but the process entails quite as much time trouble and care as Wanklyn's method, to which its results add little if anything of importance.

Unfortunately this reaction of the permanganate ("Condy's fluid") has become only partially understood by the laity, among whom there is a wide-spread impression that any water which has been rendered a distinct pink by this salt and allowed to stand for about a quarter of an hour and which does not at the end of that time show any change of colour, is, as regards organic pollution, above suspicion. No better instance of the truth of the old adage "a little knowledge is a dangerous thing," could well be adduced, for such a test when the water is alkaline—as it often will be—will not detect such quantities of animal pollution as would place the water well within the category of a dangerously polluted one—and this for the reason that two essential conditions of the test are ignored, *i.e.*, that the water should be rendered acid (to induce the permanganate to part with its oxygen), and also heated to a certain temperature (to encourage the same result).

I have not seen it pointed out that in order to avoid much error it is necessary to institute a comparison test; for, even after much practice, one is frequently under the conviction that some pink is permanent in the water when by such a comparison there is found to be no evidence of it whatever; and I have frequently tested those whom I have had to teach upon the same point, and left them astonished at their false colour impressions when I have thus demonstrated their error. The change is sufficiently well marked, of course, at the *commencement* of the process in a bad water to leave no doubt in the mind of anyone, but it is at the end of the process where the difficulty of deciding arises.

It is difficult to believe but that many incorrect results must have been furnished when the original Forchammer process or Du Chaumont's modification were widely employed, save it be with those who have had an extensive experience and possess a most delicate appreciation of colour. There is not the same *amount* of liability—though it exists—to err on this account in Tidy's modification.

My practice, therefore, is to create the same depth of pink in a similar bulk of pure water to that under analysis at the commencement of any test dependent upon the decoloration of permanganate of potassium, and to judge by this comparison whether any real evidence of pink remains in the water under analysis after the time chosen for experiment has elapsed. Though this precaution may appear at first sight to be trivial, and an addition to an already troublesome test, considerable error is sometimes thus prevented, and if it is necessary to make the estimation at all it should be necessary to conduct it with the greatest possible degree of accuracy.

It is very essential to appreciate, and always to bear

in mind, the important fact that there are other substances which water is liable to contain which will reduce the permanganate, besides organic matter:—*i.e.*, nitrites, sulphites, ferrous salts and sulphuretted hydrogen; so that it is necessary to dispose of these before attributing the reduction in the permanganate solely to organic pollution, and thus to preclude the possibility of reducing agents other than organic matter affecting the results. Since $\frac{1}{4}$ grain to the gallon of iron can be detected by the chalybeate taste which it imparts to the water, in the absence of any such taste the presence of iron may be disregarded (more especially as existing in the form of a *ferrous* salt). If the temperature of the water is brought up to near that of the boiling point any sulphuretted hydrogen is driven off; but to get rid of the nitrous acid completely it is necessary to boil the water after acidulation with sulphuric acid, for about twenty minutes;—and if the amount of oxidisable matter is estimated before and after such boiling, the amount of oxygen absorbed by nitrous acid (as nitrites) can be estimated, and thus a quantitative calculation of these salts may be effected. In the absence when tested for of any of these other reducing agents, the process can, of course, be at once commenced without any preliminary treatment.

Unfortunately the original Forchammer principle of estimating the oxidisable organic matter with permanganate of potassium has been so variously applied, that at the present day the student of water analysis can but be struck with the variety of methods adopted, and the confusion created in the various ways of returning results. The water is tested by different observers at different temperatures, and for different periods of time, by solutions of permanganate of different strengths,

from which the oxygen is liberated by different reagents. No greater confusion, no more unsatisfactory state of things can well be imagined, dealing as we are with such a salt as potassium permanganate, and a process which has some value is thus made so obscure and puzzling to many as to be rendered almost nugatory.

There may be some who are able to institute a comparison between a water which is simply returned as "0·035 part per hundred thousand of oxygen, absorbed by organic matter in 30 minutes at 140° F.," and another as "80 parts per hundred million in 4 hours at 80° F.," but unfortunately the writer is not of their number, and is loth to make any attempt to enter here upon so long and unprofitable a subject.

There is probably nothing more desirable within the scope of a chemical water analysis than that this absurd state of things should cease, and that an intelligent appreciation of results should be facilitated, if not established, by the adoption of an universally accepted mode of procedure. Fortunately Tidy's method bids fair to settle much of the difficulty, since its adoption is now rapidly becoming general. The late Dr. Tidy made some valuable improvements in the working details of the original Forchammer process, which have however of necessity made it more difficult and lengthy of performance, and those drawbacks inseparable from the test, and which have been pointed out, of course remain. In his method a certain temperature is insisted upon, as well as the employment of definite amounts of certain reagents, and it only remains for analysts to agree upon the terms in which the results shall be invariably expressed and the period of time for which each test shall be applied.

The temperature has been proved by experiment to

be a more important factor than would be imagined, and the amount of oxygen abstracted from the permanganate varies considerably at different temperatures.

Tidy's Modification of the Forchammer Process.

Reagents required:—

1. A standard solution of the permanganate of potassium 10 c.c. of which contain 1 milligramme of available oxygen.
2. A solution of potassium iodide.
3. Dilute sulphuric acid.
4. A solution of sodium hyposulphite.
5. A solution of starch.

Apparatus required:—

1. Two glass stoppered bottles of about 400 c.c. capacity each.
2. A large glass beaker.
3. Two burettes graduated in cubic centimetre and tenths of cubic centimetres.

The process:—

1. Pour 250 c.c. of the water into a thin glass stoppered bottle, and then place this inside a large stout beaker containing so much water that it rises up the sides of the bottle to well above the level of the contents. A water-bath is thus improvised.

2. Apply heat until the 250 c.c. of water in the bottle (when tested with a thermometer) have reached a temperature of 80° F., and then regulate the calibre of the flame and remove it away from the centre of the under surface of the beaker until the heat applied is just sufficient to retain the water under examination constantly at 80° F.;—this being a temperature which facili-

tates the parting of the oxygen from the permanganate of potassium and its absorption by the organic matter present.

3. Add to the 250 c.c. of water, first 10 c.c. of the dilute sulphuric acid, and then 10 c.c. of the standard solution of permanganate. The sulphuric acid liberates the oxygen from the permanganate in the following manner :—

$$2K_2Mn_2O_8 + 6H_2SO_4 = 4MnSO_4 + 2K_2SO_4 + 6H_2O + 5O_2$$

4. After two hours, (or after 1 or 4 hours as the case may be), take the bottle from the bath, and proceed to estimate the amount of *undecomposed* permanganate it contains in the following manner :—

5. Add a drop or two of the solution of the iodide of potassium, stirring well with a clean glass rod, until the pink colour is entirely removed and a yellow one (due to free iodine) replaces it ; *i.e.*, the undecomposed permanganate immediately reacts upon the iodide, with the result that an amount of free iodide is liberated proportionate to the amount of undecomposed permanganate :—

$$K_2Mn_2O_8 + 10KI + 8H_2SO_4 = 2MnSO_4 + 6K_2SO_4 + 8H_2O + 5I_2$$

The next step is to estimate the amount of this free iodide, and it is done in the following manner :—

6. Add by a graduated burette the standard solution of sodium hyposulphite until the yellow colour has nearly disappeared, *i.e.*, little free iodine remains ; and then, so as to estimate precisely when it finally disappears, create the blue colour of the iodide of starch by adding a drop or two of the starch solution ; then resume the addition of the standard solution of sodium hyposulphite until this blue colour has just disappeared. The reaction of the hyposulphite solution upon the free iodine is according to the following equation :—

$$2Na_2S_2O_3 + I_2 = 2NaI + Na_2S_4O_6$$

7. If this process of titration has been properly performed, and if the necessary amount of hyposulphite solution has not been exceeded, a drop of the permanganate solution will suffice to restore the blue colour.

8. The solution of hyposulphite is extremely liable to change, and it is therefore advisable to standardize it upon each occasion of trial by a control test as follows:—

250 c.c. of doubly distilled water are treated in precisely the same manner, and for the same time, as the water under examination, and the 10 c.c. of standard solution of permanganate should not of course be in any way affected in this case; so that when we come to titrate with the hyposulphite solution, the quantity of this necessary for the titration will be the amount which is equivalent to 10 c.c. of the standard solution of permanganate (*i.e.*, 1 milligramme of oxygen will be consumed). The difference, therefore, between the amount of hyposulphite solution required for the titration of 10 c.c. of potassium permanganate in this pure distilled water, and that required for the 10 c.c. which has been partially decomposed by oxidisable organic matter in impure water, will represent the amount of oxygen consumed by such oxidisable matter.

Example.—The *distilled* water + 10 c.c. of permanganate used up 40 c.c. of the hyposulphite solution.

∴ 40 c.c. of the hyposulphite solution may be considered as equivalent to 10 c.c. of permanganate, or 1 ***milligramme of oxygen.***

The *sample* water + 10 c.c. of permanganate used up only 30 c.c. of the hyposulphite solution, and therefore an amount of oxygen equivalent to $40 - 30 = 10$ c.c. of hyposulphite solution has been taken up by the organic matter. But if 40 c.c. of hyposulphite solution is equi-

valent to 1 milligramme of O_2, then 10 c.c. = 0·25 milligramme of O_2.

∴ 0·25 milligramme of O_2 is taken up by 250 c.c. of water (250,000 milligrammes) = 1·0 part per million, or the organic matter in a *hundred million parts of water* required 100 *parts of oxygen to oxidise* .

Notes upon the process.—The amount of permanganate added during the heating must in every case be sufficient to create a pink which remains distinctly permanent at the end of the heating,—in the case, therefore, of making the four hours' test, it is often necessary to make further additions of the permanganate solution—when careful note must of course be made of the *total* quantity which has been employed.

At the end of the process, *i.e.*, after titration, the blue colour returns when the fluid has been exposed a few minutes to the air.

Four hours is quite short enough for the test to be of much value—since it is highly probable that it is mainly the *putrescent* organic matter which is *chiefly* oxidised in the first hour.

The desirability of conducting the test in a stoppered bottle, rather than in an open beaker in which the water is exposed to the air, was pointed out by Dr. Dupré and the Society of Analysts.

Conclusions to be drawn from the amount estimated.—In a *very pure* water the oxygen thus absorbed does not exceed about 50 parts per hundred million after four hours, or about 40 parts in two hours; but a water cannot be classed as *suspicious* unless it absorbs more than about 200 parts in four hours, or 160 in two, and even in these cases no definite conclusion can be come to unless the the main nature of the organic pollution is roughly known, since a peaty water could not be judged

as harmful which required as much as 600 parts of oxygen to oxidise its organic matter in four hours, or about 450 in two hours; this is due to the fact that vegetable matter absorbs a great deal of oxygen from the permanganate,—much more so than an equivalent amount of animal matter,—and waters may contain a considerable quantity of the former (as peat) and not be generally productive of ill-health. If then the oxygen absorbed is due to this vegetable matter, there is not much ground for alarm. Unfortunately another weak point in the test thus discloses itself, for besides furnishing no indication of the *nature* of the organic matter present, the permanganate appears to give its readiest response to the least harmful of the two forms of organic pollution.

From a hygienic standpoint then, there can be no gainsaying that for many reasons the test, though useful, is not one ever likely to find a *prominent* place in water analyses; and it is to be hoped that as our knowledge of the constitution of the different forms of organic matter increases, subsequent researches will discover a more accurate and useful method which shall estimate the oxidisable organic matter which is dangerous.

Note.—The standard solution of permanganate of potassium is made by dissolving 0·395 gramme of the pure salt in a litre of distilled water. The solution of potassium iodide by dissolving 1 part of the pure salt in 10 of distilled water.

The dilute sulphuric acid, by adding 1 part of pure acid to 3 of distilled water, and a solution of the permanganate of potassium is dropped in until a very slight pink tint is discernible after four hours at a temperature of 80° F.

The sodium hyposulphite solution, by dissolving 1 gramme of the crystallised salt in a litre of water.

The solution of starch, by adding 1 gramme to 500 c.c. of cold distilled water and briskly boiling this for five minutes, and then allowing to stand and settle, when the almost clear supernatant liquid is decanted off.

CHAPTER VIII.

Dr. E. Frankland's Process.

A short abstract only of this truly ingenious process is here appended since it is too difficult and complex for any but trained chemists to perform, and it is generally thought that Wanklyn's method attains to as true an estimate of the organic matter at the cost of far less trouble. A correct appreciation of the process is necessary, however, for the Public Health student, since the chemists of the London Water Companies and the Official London Water Analyst on behalf of the Local Government Board (Dr. Frankland himself) adopt the process, and send in their returns accordingly; moreover, the analyses of the important Rivers Pollution Commissioners were thus performed. The chief reason, therefore, for introducing it here and offering a short abstract of the clever and elaborate process, is to enable the reader of such reports to understand the significance of the terms employed to express results.

The process for reasons already seen is less a favourite among Health Officers than with even the generality of analytical chemists, and it may be interesting and instructive to review the reasons of its unpopularity, together with the chemical objections which have been raised against its accuracy.

The reader will remember that it was pointed out on a previous page that the rationale of the method is as follows:—When water is evaporated to dryness and

the residue is burnt with the oxide of copper, the nitrogen and the carbonic acid which are associated with the organic matter are readily eliminated, and can then be collected and measured as "organic nitrogen" and "organic carbon" (in carbonic acid). It is evident, however, that in every case it is necessary to consider and dispose of the nitrogen and carbon which may be originally present in the water in the form of ammonia and oxidised ammonia (as to the nitrogen), and in carbonates (as to the carbon).

The chief objections raised against the process are:—

(*a*) Its cost. The expense of the mercury and apparatus is great: (a description of the latter would entail many pages of print).

(*b*) Its difficulty of performance except in the hands of trained and skilful chemists.

(*c*) The process is tedious and requires at least two days for completion. In the face of these obvious drawbacks it is maintained—and justly so—that results are certainly no more precise and trustworthy than those obtained by Wanklyn's method; and as regards the opinion which these results enable one to form upon the water, they *closely* coincide with those formed when the same water is analysed by Wanklyn's method.

(*d*) It is impossible to prevent *some* contamination from organic dust or atmospheric ammonia. This is probably a trivial objection since the evaporation is conducted under a tall glass shade.

(*e*) The fact that a large bulk of water has to be evaporated to dryness must insure *some* amount of breaking up and dissipation of the less stable organic matter; and nitric acid also remains as a further source of fallacy, especially when nitrates are abundant. In some cases it has been found that such losses may

approximate in their proportion to the total amount of organic matter which is estimated by the process.

(*f*) Inferences are drawn from the ratio which "organic nitrogen" bears to "organic carbon," and the amount of "organic nitrogen" is less reliably estimated than that of the latter. Dr. Dupré points out that sea-water shows a ratio between the two worse even than is found in pure sewage.

(*g*) The dangers of errors in working, and delays sometimes occasioned by the fracture of combustion tubes, are greater than that in any process employed in a water analysis.

The Process.

I. A litre of water is measured out and to this 20 c.c. of a saturated solution of sulphurous acid is added, in order that during subsequent heating the nitrogen in nitrates and nitrites shall be eliminated as nitric oxide, and the carbonic acid in the carbonates present shall likewise be disposed of: otherwise results would of course be valueless, since the object is to collect and estimate the nitrogen and carbon of *organic* matters *alone*.

II. Evaporate this to dryness, then intimately mix the residue, by means of a clean flexible spatula, with pure oxide of copper in a finely powdered state, and heat in vacuo in a combustion tube for about an hour: *i.e.*, until exhaustion is complete, and the gases evolved (*i.e.*, sulphurous acid, nitric oxide, nitrogen, carbonic acid and oxide, and if nitric oxide be absent—as in some cases—oxygen) have all passed over and been collected over the mercurial trough; after which they are measured volumetrically.

III. It becomes necessary to remove the sulphurous acid and also any carbonic oxide or oxygen when present. The first named is absorbed by a concentrated solution of potassium bichromate, the oxygen by a cold saturated solution of the pyrogallate of potassium, and carbonic oxide by a solution of the chloride of copper.

IV. The remaining gases will then consist of the whole of the "organic carbon" as carbonic acid, and the "organic nitrogen" as nitrogen.

V. The carbonic acid is then absorbed by a strong solution of caustic potash, and the residue is measured volumetrically as nitrogen. The nitrogen originally present in the water in the form of *ammonia* (and which has been previously estimated) is deducted, and the result is then expressed as "organic nitrogen." The "organic carbon" is represented by the loss in volume of the combined gases after treatment with the strong liquor potassæ.

By this process the purity of water is judged from a consideration of the *actual amounts* of organic carbon and organic nitrogen present, and their *relative proportions* to each other;—and both a low quantity of each and a small relative amount of organic nitrogen is favourable to the water. Much carbon and little nitrogen is indicative of vegetable pollution, whereas, on the other hand, the nearer the amount of nitrogen approximates to that of carbon the greater is the indication of the pollution being of an animal origin.

The Rivers Pollution Commissioners held that "a good drinking water should not yield more than 0·2 part of organic carbon or 0·02 of organic nitrogen in 100,000 parts;" and it seems quite justifiable to condemn a water containing as much as 0·6 part of the former and 0·04 part of the latter.

Dr. Frankland in his Reports classifies "the total combined nitrogen" in his return of the water ingredients; the term includes the quantities of organic nitrogen, the nitrogen in "free and saline ammonia," and the oxidised nitrogen of nitrates and nitrites. The utility of this collective estimation is not very apparent for we are already made acquainted with the respective quantities of nitrogen under each heading, and these vary considerably in their respective significance.

CHAPTER IX.

Oxidised Nitrogen in Nitrates and Nitrites.

Nitrates and nitrites in a water represent, in most instances, the oxidised nitrogen derived from nitrogenous organic matter, and hence denote danger. Organic matter by its putrefaction and decomposition becomes ultimately reduced to its absolute elements, of which nitrogen is one, and this nitrogen combining with hydrogen first forms ammonia; hence when "free or saline ammonia" is found in large quantities in a water it affords evidence of the actual presence of a polluting organic source, such as raw sewage. As the water continues on its course and percolates porous strata the ammonia acquires oxygen from the water, the air, or by the action of the so-called "nitrifying organisms" in the soil, and thus becomes partially oxidised to nitrous acid (HNO_2), which by combining with bases (commonly of calcium, sodium, and potassium) forms *nitrites;* the presence of these therefore indicates organic pollution, which, if not actually present, must have been very recently so. The same causes continuing to act the nitrous acid combines with more oxygen, and becomes nitric acid (HNO_3), and *nitrates* of these same bases are formed until ultimately none of the original nitrites may have escaped this further oxidation. The oxidising process cannot proceed beyond the formation of nitrates, and their presence thus indicates that owing either to the extent of dilution, or the distance travelled,

or other favourable conditions met with, some, it may be *all*, of the organic matter has been thoroughly oxidised into innocuous nitrates.

If "the two ammonias" are very small in amount then the whole of the organic matter may be considered as thus purified; when this is not the case, however, purification has only been partially effected. When, as in some rare cases, the water in its subsequent flow meets with reducing agents in the strata (either inorganic or organic), the nitrates which have been built up may become gradually deoxidised, and by successive retrograde steps become reduced to the original ammonia again.

"Their determination (nitrates and nitrites) is therefore a point of the greatest importance, for they indicate either a pollution of the water at some remote period with possibly dangerous ingredients, or the contamination of the water at the present time with partially or completely purified sewage. At any time, however, the purifying power of the filtering earth may be exceeded or overcome, and then the liquid filth may pass into the well with its dangerous ingredients unchanged and unpurified." (Louis C. Parkes, "Hygiene," Second Edition).

It is necessary, however, in all cases where nitrates exist in small amounts, before actually convicting the water to preclude the possibility of their access from the strata permeated, since waters,—as from the chalk, the oolite, the red sandstone and the Lias,—may contain marked traces (*i.e.*, 7 parts per 100,000).

With regard then to the inferences to be drawn from the presence of nitrates, we are in a similar position to that which the estimation of chlorine places us in,—with the exception that chlorine may exist much

more frequently and in much larger quantities in a *pure* water than nitrates can ever do.

When then the nitrates have not been derived from organic matter (which will be animal for the most part, and if vegetable will be mainly derived from the dangerous fungi), the water will have permeated the chalk and red sandstone formations, &c.; there will therefore be considerable hardness and mineral residue (among which will be much carbonate), and the direct evidence of organic matter will also be of a negative character—such as little "saline" and "organic ammonia," &c.

A knowledge of these facts will at once enable a true estimate of the importance of traces of nitrates to be made. The presence therefore of the slightest traces will always arouse suspicion, and demand an investigation into their source; and more especially is this the case with nitrites. Nitrites have of course a tendency to rapidly become nitrates in water, so that whereas a water may contain the latter without any evidence of the former, nitrates will always be found accompanying nitrites.

Nitrates and nitrites exist in very small quantities in most waters vitiated by vegetable matter, and chiefly because vegetable decomposition yields comparatively little nitrogen and plant life removes nitrates and nitrites from a water.

Nitrites in a river water which courses through arable districts, are sometimes excessive, from the nitrites of sodium and potassium now extensively used for artificially manuring the land.

Dr. Frankland has classified all the inorganic nitrogen present in a water, *i.e.*, that contained in nitrates, nitrites, and "free or saline ammonia"—after deducting "the average amount of nitrogen present in rain water"—as evidence of "previous sewage contamination," and

such may for most practical purposes be accepted as broadly correct; but it will be seen, from what has already been said, that a water from the chalk may discover a fallacy in so peremptory a decision, and that the rainfall over different districts often shows such varying amounts of ammonia, that "the average amount of nitrogen in rain water" is a very unsatisfactory factor to deal with.

Qualitative Tests for Nitrates.

It does not appear necessary to mention here any of the newer and on that account more fashionable tests for nitrates, since the old brucine test in careful hands will detect extremely faint traces.

A few drops of a solution of brucine* are well mixed up with half a test-tubeful of the suspected water; then with the test-tube held well on the slant against a white background pure sulphuric acid is poured gently down its sides, until it forms a distinct layer at the bottom of the test-tube. When the test-tube is brought to the vertical a pink zone is seen to occupy the line of junction between the mixture of brucine and water and the sulphuric acid; the pink is very transitory, however, and soon changes to a brownish-yellow, hence the necessity of having previously provided a white background in order that the colour shall not be missed.

A more delicate mode still of applying the same test is to place 2 c.c. of the water in a perfectly clean platinum dish and evaporate to dryness. Then a drop

* Brucine is allied to strychnine, and the solution should be a saturated one.

of pure sulphuric acid is allowed to fall into the dish, and a minute crystal of brucine is added. A pink colour will appear with extremely faint traces (*i.e.*, 0·01 parts per 100,000).

Qualitative Tests for Nitrites.

The old starch test for nitrites is sufficiently reliable and delicate, when carefully performed, for most purposes. It consists in the addition of a little clear starch solution and a drop of a solution of potassium iodide to some of the water in a test-tube. Dilute sulphuric acid is then added, and in the presence of nitrites a dark blue tint appears *immediately*,* *i.e.*, nitrous acid is liberated by the sulphuric acid, it then reduces the potassium iodide, leaving the iodine free to combine with the starch and to form the *blue* iodide.

A more reliable and delicate test, however, is that of Griess:—5 grammes of meta-phenylene-diamine are dissolved in 100 c.c. of water (the solution when not perfectly colourless must be decolourised, *i.e.*, by animal charcoal); the water is afterwards slightly acidified with dilute sulphuric acid. If 1 c.c. of this be added to 50 c.c. of the suspected water in a Nessler glass placed upon a white porcelain slab, a pale orange to a red tint according as the nitrites are present in smaller or larger amounts, is slowly created.

The solution of meta-phenylene-diamine must not be acidified too strongly, and in every case after applying the test time must be allowed for the reaction to take

* Frequently nitrates will give a similar reaction after standing a while, due to the reduction of some of the nitric acid to nitrous acid; so that an *instant* reaction is a necessity to this test.

place. In cold weather the water should be slightly warmed, and in cases of very faint traces indeed the colour does not develope in less than half an hour, and this fact must be allowed for in the process of titration or difficulty and error will result.

The reader is aware of the importance of learning whether nitrites, apart from nitrates, exist in a drinking water, and unfortunately the matter is not an easy one since they respond similarly to most tests and they frequently co-exist in a water. The most reliable and simple mode of detecting a nitrite in the presence of a nitrate is the following:—Add a little of the solution of potassium iodide and starch, a small quantity of powdered metallic zinc, and then render acid with acetic acid. If nitrites are present a blue colour appears—of the iodide of starch—but not so with nitrates *alone*, even after waiting a little.

The Quantitative Estimation of Nitrites.

There is nothing to be gained from the trouble and work entailed in this estimation since the mere presence of nitrites is sufficient to condemn the water.

The estimation is commonly based upon Griess' test, and the degree of colour thus created is matched by adding a standard solution of potassium nitrite (1 c.c. = 0·01 milligramme of NO_2) to a similar quantity of distilled water which has been otherwise treated in like manner to the suspected water, in another Nessler glass.

Example.—It took, say, 8 c.c. of the standard nitrite solution to create in the comparison Nessler glass the same tint of colour which the nitrous acid present in

the water sample creates, and therefore the amount of NO_2 in the sample of water is equivalent to that contained in 8 c.c. of the standard solution.

But 1 c.c. of this $\triangleq$ 0·01 milligramme of NO_2.

Therefore 8 c.c. = 0·08 milligramme of NO_2.

Therefore there are 0·08 milligramme of NO_2 in 50 c.c. (or 50,000 milligrammes) of water, or 0·16 milligramme of NO_2 in 100,000 milligrammes.

The atomic weight of nitrogen is 14, and that of oxygen is 16. Therefore the combined atomic weight of $NO_2 = 46$. Therefore $\frac{14}{46}$ (*i.e.*, 0·16) of the amount of NO_2 will represent "*the nitrogen in nitrites*" = 0·048 *parts per* 100,000; and this is the form in which results are generally returned.

Note.—The standard solution of potassium nitrite is made of the required strength by dissolving 0·406 gramme of pure silver nitrite in hot water, and decomposing it with a slight excess of potassium chloride. This is allowed to cool and the solution is then made up to one litre; allow the chloride of silver to settle, and dilute each 100 c.c. of the clear supernatant liquid again to one litre; one c.c. of this liquid contains 0·01 milligramme of potassium nitrite.

The Quantitative Estimation of Nitrates and Nitrites.

The most convenient method—while at the same time it appears to be as reliable as any of the other numerous processes to the same end—is that known as the *copper-zinc process*, by which all the oxidised nitrogen in nitrates and nitrites is converted into ammonia in the presence of a wet copper-zinc couple. The amount of the am-

monia thus obtained can be readily estimated as in Wanklyn's method, and taken as an index of the nitric and nitrous acid from which it was originally derived.

Apparatus required.—1. A small wide mouthed glass stoppered bottle.

2. A boiling flask.

3. A condensing apparatus.

4. Nessler glasses.

Reagents required.—1. Clean thin zinc foil.

2. A concentrated solution of cupric sulphate, about 3 per cent.

3. Occasionally some pure sodium chloride and oxalic acid.

4. The reagents for Griess' test for nitrites.

5. The Nessler reagent, and standard chloride of ammonium solution.

The Process.

1. A wet copper-zinc couple is prepared by taking a piece of thin well crumpled zinc foil—clean and bright—measuring about 3 inches by 2 (of about three grammes weight), and covering this with a concentrated solution of copper sulphate (about 3 per cent.).

Very quickly the bright surface of the zinc loses its metallic appearance and becomes tarnished with a black adherent coating of metallic copper, which envelopes the foil. As soon as this has thoroughly formed, and generally from 3 to 6 minutes will suffice, the zinc with its copper coat is removed, or the coating becomes pulverulent and falls away. It is then well washed with distilled water, and next with some of the sample under analysis. Finally it is placed in a thoroughly

clean 8-ounce glass stoppered bottle, armed with a wide mouth in order that it may take the metal.

2. 100 c.c. (or 250 c.c.) of the water under analysis are poured in so as to cover the "couple," and the bottle is stoppered and left all night in a warm place (65° to 85° F.).

With very soft water a trace of sodium chloride should be added, and with very hard ones a small quantity of pure oxalic acid to precipitate the lime. Both these additions where they are required will accelerate the reaction, as will also the warming of the water to about 100° F.

3. On the following morning the water is decanted into a boiling flask, and 400 c.c. of ammonia free distilled water are added. At this stage a little of the water should be tested for nitrous acid by Griess' test;—the absence of this acid proves the completion of the process, and its presence demands that the reaction should be given more time to complete itself in.

4. The water is then distilled until all the ammonia present has come over. This is then Nesslerized as in Wanklyn's method, and the *nitrogen* present is calculated from the ammonia formed thus:—

The atomic weight of ammonia $= N(14)H_3(3) = 17$, therefore $N = \frac{14}{17}$ of the ammonia estimated.

Of course the amount of free ammonia originally present in the water, and which has already been estimated by Wanklyn's method, must be deducted from the total ammonia estimated by this process.

Example.—The 500 c.c. furnish 0·25 milligrammes of ammonia, all of which must have been yielded by the 100 c.c. of sample.

There is therefore 0·25 milligramme of ammonia in 100 c.c. of sample water (or 100,000 milligrammes).

But by Wanklyn's method the water showed eight parts per hundred million of "free ammonia" or 0·008 parts per 100,000.

Deducting this amount therefore (0·25 − 0·008 = 0·242) there are 0·242 parts of ammonia due to nitrates and nitrites in 100,000 parts of the water sample.

The results are now almost invariably expressed in terms of "*nitrogen as nitrates and nitrites*," and nitrogen has been seen to form $\frac{14}{17}$ of ammonia, therefore there are $\frac{14}{17}$ of 0·242 = 0·199 of "*nitrogen as nitrates and nitrites*" in 100,000 parts of water.

If it should be desired to estimate the nitrogen of the *nitrates* alone, the nitrogen yielded by *nitrites* must be deducted. This is rarely, if ever, done now for any practical purpose; but the matter is a simple one. The water has been found by Griess' method to contain nitrogen as nitrous acid to the extent of 0·048 parts per 100,000.

The amount of nitrogen therefore which must be deducted on account of that furnished by nitrites = 0·048, and 0·199 − 0·048 = 0·151, *i.e.*, the amount furnished by nitrates alone in 100,000 parts.

Notes upon the Process.

It is a question whether the presence of organic matter does not destroy the accuracy of the results, as pointed out by Frühling. If, however, such is the case to any material degree, and it does not appear to be so, the water could first be distilled with alkaline permanganate of potassium.

It seems better that the conversion of nitric and nitrous acids into ammonia should be allowed to take

place without the addition of any marked degree of heat, else some ammonia appears to be lost, probably owing to the escape of nitrogen as such.

If the ammonia is in large quantities and its colour cannot on this account be matched by the chloride of ammonium solution, it can best be estimated by dilution of the distillate with distilled ammonia free water, as previously recommended (*vide* "Wanklyn's Method").

Conclusions to be drawn from the amount estimated.—The faintest trace of nitrites will always arouse the greatest suspicion, and when the "nitrogen in nitrates and nitrites" exceeds 0·1 part per 100,000, suspicion is likewise justified in those cases where the strata may be excluded as the source from which the water derives such salts.

CHAPTER X.

Chlorine.

Chlorine exists in water chiefly as chlorides of sodium and calcium, and only occasionally as magnesium chloride.

Chlorine is present in all waters to a small extent, even in rain water, since all atmospheres contain sodium chloride in suspension. It is only when its presence is marked that suspicion is aroused as to its origin.

The presence of an excess of chlorides in water is due to either one of the following causes:—

(a) A mixture with sea water, as in tidal rivers.

(b) Open reservoirs and other expanses of fresh water near the coast, also show excess—due to the fact that the atmosphere contains larger amounts of sodium chloride than is usual elsewhere, and this in part gets deposited upon the surface of such waters and is at once dissolved.

(c) Deep wells by the sea coast, or those in which the water has previously percolated strata into the composition of which saline constituents enter, *i.e.*, greensand, sandstone, the London clay, and to a less extent the chalk*—yield water rich in chlorides. In the districts of salt deposits the water may contain very large quantities of chlorides.

* Such waters may contain twenty parts per 100,000 of chlorine.

(d) Pollution by animal organic matter, chiefly urine;—in which case sulphates will also be in excess.

The presence of chlorine in excess is thus seen—after excluding any possibilities the water may have run in acquiring its chlorine from sources (*a*) (*b*) and (*c*)—to indicate organic contamination, and that of an animal nature, since vegetable pollution *per se* creates no excess in this respect; hence in these cases the estimation affords a most important means of determining as to whether a vitiated water is polluted by animal or by vegetable matter. It follows, then, that although the presence of but little chlorine is pretty conclusive evidence of the water's purity as regards animal pollution, it could not under ordinary circumstances be used as a rapid means of gauging the general purity of a water, since such may be injuriously contaminated with vegetable matter, or even with organic effluvia, and give no evidence of these in any excess of chlorine. When, however, the amount of chlorine which the purest waters in the district contain is known, a water may be quickly judged—as regards animal pollution—by testing for chlorides alone, and noting if there is an increase of these.

It remains now to be seen, apart from any other information which has been furnished or which is available, what *chemical* means there are of excluding causes (*a*) (*b*) and (*c*), as creating excess of chlorine. Well! we are so generally dependent upon water which has come in contact somewhere in its course with the chalk formation, in England, that the difficulty which will probably most often arise is to decide as to whether excess of chlorine is not due to the fact that the strata from which the water has been collected, or over which

it has coursed, contains soluble chlorides; rather than to the presence of animal pollution. The matter fortunately becomes an easy one to decide upon when it is borne in mind that if the excess be derived from the strata the total solids will be *high and entirely of a mineral nature*, and there will be no evidence of organic pollution furnished by those other stages of the analysis which aim at detecting such pollution; except it be in the fully oxidised nitrogen ("nitrates"),—for strata containing soluble chlorides generally contain soluble nitrates also, in less degree.

If, on the other hand, the excess be due to animal pollution (it cannot be to vegetable!), the total solid residue, though it may be high, will contain much organic matter, and there will be further evidence of the nature of the contamination all along the line of those steps of the analysis which serve to indicate such pollution.

If a large amount of chlorine be due to admixture with sea water there will also be present large quantities of magnesium salts, which fact enables a decision at once to be made upon this score. A specimen of sea water collected by the late Dr. Tidy during high water at Margate gave:—

Chlorine	1239	parts per 100,000.
Lime	24·5	
Magnesia	144	

Qualitative Test.

The presence of chlorides may be best detected by the addition of a few drops each of a solution of silver nitrate and dilute nitric acid to the water in a test-tube,

when a white haze, turbidity, or precipitate of argentic chloride will appear, according to the amount of chlorine present.

Quantitative Test.

Apparatus required.—This is of the simplest nature :—

1. A burette graduated in tenths of cubic centimetres, fixed upon a stand, and fitted with a stopcock.
2. A white porcelain basin capable of holding a little over 100 c.c. of water.
3. A glass stirring rod.
4. A measuring flask for 100 c.c. of water.

Chemical reagents :—

1. A solution of the yellow chromate of potassium, which, since it is to be added to the water, must obviously be free from chlorine.
2. A standard solution of silver nitrate, made to the strength that 1 c.c. is capable of precipitating 1 milligramme of chlorine.

The Process.

1. Measure out 100 c.c. of the water and place it in the white porcelain dish.
2. Add a few drops of the solution of yellow chromate of potassium until a faint—though distinct—yellow colour is created in the water. The object in creating this colour is to make it serve as an "indicator," which shall denote at once the stage when all the chlorine has been precipitated.
3. Some of the standard solution of nitrate of silver is

taken up in the burette and then added drop by drop to the water, when a dull red precipitate is at once formed of the red silver chromate; this when stirred up in the water by means of the glass rod at once disappears, owing to the chlorine in the water displacing the chromic acid and itself combining with the silver, to form a white precipitate of the chloride of silver. As the addition of the standard solution is continued, the water, though it retains the yellow colour, becomes very turbid, owing to the accumulation of this precipitate of silver chloride; and at length a point is reached, at which, there being no longer any chlorine left which is not already combined with the silver, the chromic acid holds undisputed possession of this metal, and the red silver chromate remains permanently present;—the first evidence of this is afforded by the yellow colour changing into an orange. After further addition of the silver salt the whole solution becomes a dull red.

The motive for originally adding the "indicator," *i.e.*, the yellow chromate of potassium, becomes very evident by this stage, since there would otherwise be no means of knowing when just the required amount of silver nitrate had been added; for it would be impossible to judge of the exact stage when the maximum amount of white precipitate of silver chloride had been created.

4. The first evidence of any red colour remaining permanent, so as to create with the original yellow an orange colour, should be the clue for withholding any further addition of the silver nitrate—or the amount of chlorine, estimated as it is from the amount of the solution of the silver salt used, will be over-estimated.

5. It is then seen by the burette how much silver nitrate solution has been added, and each c.c. of this will represent 1 milligramme of chlorine.

Example.—5 c.c. of the standard solution of silver nitrate were required to exhaust the chlorine in 100 c.c. of water.

But 1 c.c. of the solution = 1 milligramme of chlorine

∴ 5 c.c „ „ = 5 „ „

∴ there are 5 milligrammes of chlorine in 100 c.c. of water.

But 100 c.c. of water = 100 grammes = (100,000 milligrammes).

∴ there are 5 milligrammes of chlorine in 100,000 milligrammes of water, or 5 *parts per* 100,000.

If 70 c.c. of the water had been originally taken, the estimation would be made as follows:—

3·5 c.c. of the standard solution of silver nitrate were used by the chlorine in 70 c.c. of water.

But 1 c.c. of this solution = 1 milligramme of chlorine

∴ 3·5 c.c. „ = 3·5 „ „

∴ there are 3·5 milligrammes of chlorine in 70 c.c. of water.

But 70 c.c. is "a miniature gallon" in which the grains of the imperial measure are represented by milligrammes.

∴ There are 3·5 grains of chlorine to the gallon, or $\frac{3{\cdot}5 \times 10}{7} = 5$ parts per 100,000.

Conclusions to be drawn from the amount estimated.—It is not necessary, since it is invariably present in the purest waters, (rain water for instance commonly containing as much as 0·5 parts per 100,000), to grow suspicious of the presence of chlorine until it reaches the proportion of 3 parts per 100,000; above which it becomes desirable to ascertain its source. It must always be borne in mind, however, that its presence in excess can only be attributed to animal organic pollution after the

likelihood of certain other sources having furnished it have been excluded. Deep well waters in saliferous strata may yield as much as 15 parts per 100,000 in cases where the water is absolutely free from animal pollution.

Notes upon the Process.

It is highly important that neither the water nor the standard solution of silver nitrate should be acid, or the results are incorrect—since the red silver chromate, being soluble in an acid medium, is dissolved, and does not remain to create the orange colour at the precise stage when all the chlorine has been exhausted. In these cases a grain or two of pure anhydrous sodium carbonate should be added to effect neutrality, or even faint alkalinity.

The chlorine is sometimes—in order that its amount shall be more readily appreciated by the laity—expressed in the terms of the common salt it is equivalent to. This is readily calculated by a comparison which the atomic weight of chlorine bears to the combined atomic weights of NaCl (common salt).

The atomic weight of chlorine is 35·5, and that of sodium is 23 ∴ NaCl = (35·5 + 23) = 58·5

$$\therefore \text{Cl} = \frac{35{\cdot}5}{58{\cdot}5} \text{ of NaCl.}$$

Now the chlorine in the example taken amounted to 5 parts per 100,000; let x = the amount of NaCl this is equivalent to; then $5 = \frac{35{\cdot}5}{58{\cdot}5}\ x$

$$\text{or } x = \frac{58{\cdot}5 \times 5}{35{\cdot}5} = 8{\cdot}2$$

∴ there are 8·2 parts of NaCl per 100,000.

The effluents from sewage farms generally show such a small amount of chlorine that it frequently does not much exceed the limit necessary to arouse suspicion in a drinking water.

In using an unmounted graduated burette it is always as well to fill it with the solution being used up to the highest mark upon it, *i.e.*, in this case exactly up to the 10 c.c. mark—so that the height to which the solution originally stood, before any of it was removed, shall in every case be the same; otherwise, by the end of the process, the exact level to which the burette was charged may have been forgotten (that is if trouble has not been taken to note it down upon paper), and in consequence a repetition of the whole test becomes necessary at the sacrifice of time and material. When the delivery from the burette is controlled by the hand, it should be held vertically with the index finger guarding the upper extremity, and it is only after a little practice that the amount escaping from the lower extremity can be nicely controlled. When it is desired to regulate the escape in drops, the pressure of the index finger (which must be perfectly dry) upon the top of the burette, is only *gently relaxed*,—that is to say, almost imperceptibly lessened; otherwise the contents will escape too rapidly.

Solution for the Estimation of Chlorine.

In order that the standard solution of silver nitrate shall be of the strength that 1 c.c. will precipitate 1 milligramme of chlorine, it is necessary to add to 1 litre of distilled water 4·788 grammes of pure silver nitrate.

CHAPTER XI.

The Poisonous Metals.

Those metals which may in this connection be classed as "poisonous," and for which it is commonly necessary to test a water, are lead, iron, copper and zinc.

Water, under favourable circumstances, will be found most generally to take up these metals either from the pipes through which it has been made to flow, from the receptacles in which it has been stored, or from the materials used in making or repairing the joints of such pipes or cisterns; but in addition, such metals may gain access from trade-processes carried on by river sides, or from metalliferous mines within the district.

Lead is taken up from pipes and cisterns made of this material, and the action of the water upon this metal is primarily an oxidising one—highly oxygenated waters are therefore the most active; such action is greatly aided by the presence of nitrates, nitrites and chlorides, and is favoured by either neutrality or slight alkalinity of the water—(acidity, however, is even more important, since it aids the power of the water to carry the lead in solution). Since hard waters form a protecting coat to the pipes, &c., it follows that soft waters have the greatest plumbo-solvent action.

The circumstances being favourable then, the surface of the metal is oxidised to plumbic oxide, which latter is dissolved and carried away by the water as quickly as it is formed; and in those cases where there is

excess of carbonic acid present in the water, some carbonate of lead may be produced and held in solution.

A chalybeate water contains its **iron** in the form of carbonate, and this is held in solution by free carbonic acid; on exposure to air, however, hydrated ferric oxide or "rust" is thrown down ($4FeCO_3+O_2+2H_2O=2Fe_2O_3H_2O+4CO_2$),—rust being insoluble in water containing no free carbonic acid. Upland, moorland, and some other waters, (as those from the green sand and new red sandstone), generally contain traces of iron, which are taken up from the soil and strata permeated.

Copper is sometimes given to water by culinary utensils made of this metal, for a small amount of copper is dissolved when water which contains common salt, acid (vinegar, &c.), fatty or oily material, is boiled in contact with it. It is an occasional and highly condemnatory practice by cooks to place a penny into the saucepan in which vegetables are boiled, in order to improve their colour, and the writer has recorded an instance where this practice gave rise to symptoms of copper poisoning in a household.

Zinc is most generally taken up from the galvanised iron with which the water has come in contact. It generally exists in water in the form of bicarbonate, but is never present except in very small traces. Galvanised iron must not be held to entail much danger in its use, unless the water contains much free carbonic acid, since under common conditions the zinc oxide or basic carbonate form, and protect the subjacent metal from further action.

Lead and copper being cumulative in their actions, small and apparently insignificant traces may in time lead to symptoms of chronic poisoning. The smallest possible trace, therefore, of these metals should theoreti-

cally be considered sufficient to render condemnation of the water justifiable. Iron is not dangerous to the same extent, and since it gives indication of its presence when in such amounts as would not make its ingestion undesirable, by imparting a distinct taste to the water, its powers for evil on this account are almost nullified—for people will not, as a rule, drink water possessing an unpleasant taste.

Zinc never exists but in very small traces, and since it is not a cumulative poison, the possibility of danger from this metal is very limited.

Apparatus required:—

1. Two white porcelain dishes.
2. A glass stirring rod.
3. A burette graduated in cubic centimetres and tenths of cubic centimetres.

Chemical reagents:—

1. A solution of the yellow chromate of potassium.
2. ,, ,, ammonium sulphide.
3. ,, ,, the ferrocyanide of potassium.
4. Liquor ammoniæ.
5.* Dilute hydrochloric acid.
6. Copper turnings.
7. A standard solution of lead acetate, 1 c.c. = 1 milligramme of lead.
8. A standard solution of copper sulphate, 1 c.c. = 1 milligramme of copper.
9. A standard solution of iron proto-sulphate, 1 c.c. = 1 milligramme of iron.

* Dilute acid solutions generally indicate about 1 part of strong acid to 9 of distilled water.

The Process.

1. To about 100 c.c. of the water placed in a white porcelain dish, apply a little of the ammonium sulphide solution upon the glass rod. By allowing the rod to descend gently through the water, and noticing any change in the latter immediately adjacent to the rod, faint quantities of poisonous metals will be more readily detected than by allowing a drop of the reagent to fall into the water and then stirring. The reason for this is that the reagent itself imparts colour, and it is therefore advisable to add as little of it as possible to commence with;—otherwise a faint discoloration caused by a metal may be lost in that created by the reagent.

2. Any evidence of a dark colour appearing in the water denotes the presence of lead, iron or copper, and the reagent should be added until the *maximum* amount of darkening has been produced. If there is any colour present in the *original* water, a comparison must be made—before and after the application of the reagent—with a similar quantity placed in another porcelain dish, before it is decided whether any additional colour has been created by the ammonium sulphide. Where, however, the colour originally present is marked (as by peat, &c), it may well obscure, even with these precautions, such a slight presence of lead, iron, or copper, which would otherwise make itself manifest. In these cases it would be well, especially where there is any cause whatever for suspicion, to evaporate 100 c.c. of the water to dryness, burn off the organic matter from the solid residue (and with it the colouring matter will also be destroyed when this is due to peat) and

then having dissolved the residue, to proceed to test the solution.

3. Next add a drop or two of dilute hydrochloric acid; if the colour disappears the metal is *iron*, or if it diminishes perceptibly iron is present, whatever else there may be.

A confirmatory test should then be applied to some of the original water in a test-tube, *i.e.*, a drop or two of the acid is added, and then a few drops of the solution of the ferrocyanide of potassium, *i.e.*, just sufficient to create the maximum amount of colour. The dark blue colour thus created by iron salts is called "Prussian" when formed by ferric salts, and a paler blue ("Everett's salt") is formed by ferrous salts. A solution of potassium ferricyanide will give with ferric salts a reddish-brown colour, and with ferrous salts a dark blue precipitate ("Turnbull's blue"), and hence by using a mixture of ferro- and ferricyanide of potassium a dark blue would be formed in the presence of either ferric or ferrous salts, and such may therefore be employed with advantage.

4. If, after adding the hydrochloric acid, the colour does *not* disappear, the metal is either lead or copper.

First test for lead, which is the commoner of the two, by adding to some of the original water in a test-tube, a few drops of the yellow chromate of potassium,—when, if lead be present, an opacity appears in the water (due to the formation of lead chromate) and the yellow colour which has been created by the chromate of potassium, and which has a slight greenish tint in it, is deepened and changed to more of a canary hue. The reaction is, however, comparatively slight, and difficult of appreciation; and faint traces of lead will often be missed by this test unless a careful comparison is always instituted

with another test-tube containing a similar amount of pure water and reagent. Under these conditions so little as $\frac{1}{30}$ grain to the gallon* can *sometimes* be detected, if the water is either quite clear at the outset, or has been rendered so by filtration.

The ammonium sulphide reaction is itself an extremely delicate test for lead, and to the novice will be found not to present the same difficulties as the chromate of potassium test; but since copper and iron will furnish the same reaction, their presence must be most carefully excluded before lead is ascribed as the cause of the darkening. One-tenth of a grain to the gallon can always readily be detected by either of these methods, but where smaller quantities than this exist, the water must be considerably reduced in bulk by evaporation before the test is applied.

It is important to bear in mind that iron is liable to be present along with lead, and may contribute to the darkening created by the ammonium sulphide; the possibility of this taking place may be, however, excluded by adding a drop of dilute hydrochloric acid to the water,—for this has been seen to prevent or remove any darkening created by an iron salt.

Dr. Garrett has devised by far the most delicate test for lead. He claims that it will detect $\frac{1}{200}$ grain per gallon, and the writer's experience closely corroborates this. The author of the test directs that $\frac{1}{2}$ ounce of water be placed into a narrow test-tube, and one drop of dilute hydrochloric acid be added to obliterate iron. One drachm of strong freshly prepared sulphuretted hydrogen water, and $\frac{1}{2}$ grain of sulphate of barium are then added, when the whole is well shaken and set

* The quantities of metals are so universally expressed in terms of grains per gallon that it is thought best to adopt these terms here.

aside. The insoluble barium sulphate (used in the form of powder) collects, and carries down with it the sulphide of lead, "the presence and quantity of the lead being declared by the degree of colour imparted to the white powder." This white powder in settling forms two layers, and it is in the upper one of these that lead imparts a coloration, varying from "the palest Indian grey or buff to the darkest brown."

5. To test for copper, a drop or two of a solution of the ferrocyanide of potassium should be added to some of the original water after it has been acidulated with a drop of dilute hydrochloric acid (since the reaction does not take place in an alkaline liquid). If copper be present, a bronze coloration and precipitate of cupric ferrocyanide appears, which is best detected by holding the test-tube against a white background.

A corroborative test consists in adding to some more of the water, a drop or two of liquor ammoniæ, when a faint blue colour is created—which will often be missed unless it be looked for through the depth of the water on to a white background.

6. When no darkness is created in the water, a fresh amount should be placed in a test-tube, and tested for zinc, by adding a drop or two of liquor ammoniæ (and *no more*, since the precipitate formed is soluble in excess). This white precipitate created in the presence of zinc (and consisting of zinc sulphide) when once seen will always be recognised, since it has marked characteristics, *i.e.*—it is copious, and of a flocculent, curdled, and gelatinous appearance. A drop or two of dilute hydrochloric acid will dissolve it up, and on adding ammonium sulphide it can be made to reappear.

As an additional test, the ferrocyanide of potassium

will give a white gelatinous precipitate of zinc ferrocyanide, insoluble in dilute acids.

7. The presence of arsenic, which would exist in water in the form of arsenious acid (As_2O_3), has very rarely to be tested for, but when it is desirable or necessary to do so,—as notably in the case of water taken from the neighbourhood of manufactories of aniline colours, or where the soil is rich in arsenic,—Reinsch's test is the most readily performed.

Reinsch's test consists of first placing in a test-tube a bright piece of copper turnings or filings, adding a little dilute hydrochloric acid, and then boiling well; when if the brightness of the metal is unimpaired, the *materials* employed are themselves proved free from arsenic. The water is next added, and the whole heated together for several minutes, when—upon cooling—if arsenic is present a grey film of cupric arsenide forms on the bright bronze-coloured copper turnings; this may then be removed, washed, dried, and placed within a wide glass tube to which a Bunsen flame is subsequently applied; the arsenic then gets oxidised to arsenious oxide, which is sublimed, and deposited in the form of a white ring round the inside of the tube beyond the flame. This deposit can then be removed and examined under the microscope for the characteristic minute octahedral crystals.

Having thus detected the presence of either lead, iron, copper, or zinc, it becomes necessary to estimate the extent to which they exist in the water.

The Process.

1. Measure out "a miniature gallon" (70 c.c.) of the water which has been found to contain—say lead, and pour into a white porcelain basin.

2. Place a nearly similar amount (about 60 c.c.) of distilled water into a second precisely similar dish.

3. To each basin add—say two drops of the ammonium sulphide solution,* and stir both well with a glass rod, each rod being carefully reserved to its own water.

4. Whereas the water containing lead darkens, there will be no such darkening in the miniature gallon of distilled water. Add to this latter, by the burette, the standard solution of lead acetate (1 c.c. = 1 milligramme of lead), well stirring the while, until the amount of darkening created, exactly resembles that in the miniature gallon of water which originally contained the lead, and then make up the 70 c.c. with distilled water.

5. Read off the number of cubic centimetres of the standard solution required to effect this match, and this number will contain the amount of lead in the original water.

Example.—The amount of standard solution required by the 70 c.c. of distilled water to match the coloration in the sample of lead polluted water, was to the extent of 2 of the $\frac{1}{10}$ divisions into which each of the 1 cubic centimetre measures are marked upon the burette.

$\therefore \frac{2}{10} = \frac{1}{5}$ of a cubic centimetre of the standard solution was required.

But 1 c.c. = 1 milligramme of lead.

$\therefore \frac{1}{5}$ „ $= \frac{1}{5}$ „ „

$\therefore$ there is $\frac{1}{5}$ milligramme of lead in 70 c.c. of water.

But 70 c.c. is "a miniature gallon" in which the milligrammes represent grains in the Imperial measure.

$\therefore$ there is $\frac{1}{5}$ *grain of lead to the gallon of water.*

Since the method of making a quantitative estimation

* Or advantage may thus be taken of the chromate of potassium reaction if preferred.

of one of the metals is so precisely similar to that employed with any of the others, it will suffice if mention is made of the only and obvious difference, *i.e.*, that of the reagent employed. The standard solution must of course consist of a salt of the metal to be estimated in each case:—for lead, a solution of lead acetate has been used; but for copper, the standard solution is made of copper sulphate; for iron, of the protosulphate of iron.

The quantitative estimation of zinc* can be conveniently made by taking a measured quantity of the water (which is found to be free from other poisonous metals), adding ammonium sulphide solution, and collecting the precipitate of zinc sulphide on a filter; this is then well washed with dilute ammonium sulphide, dried, ignited in a weighed capsule—at a bright red heat, allowed to cool, and finally weighed as oxide.

Conclusions to be drawn from the amounts estimated.—Opinion has been a good deal divided as to the amounts of the poisonous metals in a water which may be considered as dangerous. In the case of lead $\frac{1}{10}$ grain to the gallon is generally accepted, and $\frac{1}{20}$ is advocated by some excellent authorities. It would appear best—because it is safer—rather to make an over-estimation of the danger than to run the risk of erring in the other direction, and in the case of the poisonous metals which are cumulative in their action, it is difficult to see what amount, however small, can be accepted as a limit to such powers. Is it not best then in the case of lead and copper to condemn a water containing more than $\frac{1}{20}$ grain of either?

* The estimation of zinc by means of potassium ferrocyanide, with copper sulphate paper as indicator, is slowly superseding this older process. There is liability to error, however, except certain precautions are taken.

With regard to zinc which is not a cumulative poison —undesirable as its presence is—a little more latitude may be allowed, and a $\frac{1}{4}$ grain to the gallon may be permitted; but the faintest traces of arsenic—an exceptionally poisonous and somewhat cumulative metal—should suffice to condemn the water.

Iron should under no circumstances exceed $\frac{1}{2}$ grain per gallon, except when the water is taken solely for medicinal purposes—as this quantity will provoke dyspepsia, general malaise, headache, &c., in those susceptible to its action.

Notes upon the Process.

In making the quantitative estimation of these metals, if the water contains considerable coloration before the ammonium sulphide has been added, and which cannot be safely disposed of in the manner already indicated, an attempt must be first made to estimate the value of this with reference to the standard solution employed, *i.e.*, to ascertain the quantity of the latter which is required to create the same degree of coloration in distilled water to which the ammonium sulphide has been added,—in order that this amount may be deducted from the total standard solution it is necessary to add to the distilled water and ammonium sulphide, to match the total coloration in the polluted water.

In highly coloured waters a deduction of 0·5—1 c.c. of the standard solution would have to be made on this account. The quantitative tests for metals existing in small amounts, is a very delicate one, in which a slight error effects very largely the results, so that it is preferable in those cases where no loss by volatilisation is to

be feared—since it disposes of a highly probable source of fallacy—to remove the colouring matter where possible in the manner already shown, rather than to attempt to match its colour, which is often of a some what different character, and therefore difficult to gauge by comparison.

Though the metals lead, copper, and iron, when existing in very faint traces, will generally be detected by testing the original water, yet in order to make their presence more evident, and their quantities more readily estimated, it is often desirable to reduce the bulk of the water—and thus concentrate their solutions as it were—by evaporation. In the case of zinc, which will generally exist in the form of bicarbonate, it will *always* be necessary to thus reduce the original bulk of the water, and during the process of evaporation the metal will frequently, after a time, indicate its presence by forming a thin film of carbonate upon the surface of the water.

A litre of water should in these cases be evaporated down to 100 c.c. in some material which will not in the process yield any metal to the water—such as porcelain; and any precipitate which may be deposited (such as ferric oxide), should be re-dissolved with a little dilute hydrochloric acid.

The quantitative estimation of iron and copper may also be made from the ferrocyanide of potassium reaction; but only just sufficient of the reagent should be added to create the maximum amount of colour, for a large excess will give a yellowish tinge to the water, and this impairs very materially the facility of effecting a colour comparison.

Solutions for the Quantitative Estimation of Metals.

The standard solution of lead is made by dissolving 1·66 grammes of crystallised acetate of lead in one litre of distilled water.

The standard solution of copper, by dissolving 3·93 grammes of the sulphate of copper in one litre of distilled water.

The standard solution of iron, by dissolving 4·96 grammes of the protosulphate of iron in one litre of distilled water.

CHAPTER XII.

The Non-poisonous Metals. Sulphates. Phosphates.

Nothing of any practical value, in a Public Health respect, is gained by prosecuting an investigation under this head beyond what is necessary to determine the presence and amount of calcium, magnesium, and silica.

The presence of *lime*, which mainly exists as the bicarbonate and sulphate in a water, may be discovered by creating the white precipitate of the oxalate of calcium, by adding powdered oxalate of ammonia, and then well stirring with a glass rod. If it be desired to make a quantitative estimation, a measured quantity of water, say 250 c.c., must be thus treated, and the precipitate filtered—until the filtrate is quite clear—through a small *Swedish* filter paper (of which the weight of ash it will yield after ignition is known). The oxalate of calcium precipitate remaining on this filter paper is then thoroughly washed with hot distilled water, and afterwards dried in the water oven at a temperature of 212° F., until a constant weight is got. If the weight of the filtering paper is previously known, the difference between this and the total weight will be due to the calcium oxalate; or to be more accurate and so as to insure that *all* the water shall be thoroughly driven off, the filter paper should be folded up, placed in a small porcelain crucible (previously weighed), covered by a lid and then ignited—at first gently so as to obviate spurting and loss, and the lid should be removed after a little for free access

of air. When the filter paper has been entirely destroyed ("burnt off") the lid is then replaced, and the whole allowed to cool under a desiccator, after which it is weighed. The weight found, minus that of the crucible and the ash of the filter paper, represents the weight of the calcium salt (CaC_2O_4), of which calcium forms $\frac{5}{16}$: or the precipitate may be weighed as carbonate.

Magnesia mainly exists in water in the form of the carbonate and sulphate, and chiefly in that collected from the dolomite strata, and if these salts exceed 5 grains per gallon they are apt to cause dyspepsia and diarrhœa in those unaccustomed to the use of the water containing them. The presence of magnesia may be best ascertained by precipitating all the calcium present in the water, by means of powdered oxalate of ammonia, and filtering until the filtrate is perfectly clear and free from calcium. The filtrate should next be concentrated by boiling, and then a few drops each of a solution of phosphate of sodium and chloride of ammonium are added, and sufficient liquor ammoniæ to create strong alkalinity. The whole is well stirred up with a glass rod, and then set aside for several hours, when a crystalline precipitate of a double phosphate of magnesium and ammonia (ammonium-magnesium phosphate or "triple phosphate") is formed.

The *amount* present is roughly, and most readily, estimated from the hardness which it will create when a water perfectly freed from calcium by the oxalate of ammonium, is tested by the soap solution (*vide* "Hardness"). Supposing for instance, 5 c.c. of the soap solution are required to satisfy the hardness remaining in 100 c.c. of the water: deduct 1 c.c. (the amount of solution required for an equal bulk of pure distilled water) = 4 c.c.

But 1 c.c. of soap solution = 1 milligramme of calcium carbonate.

∴ 4 c.c. = 4 milligrammes of calcium carbonate.

∴ The hardness due to magnesium salts in 100 c.c. of water is equivalent to 4 milligrammes of calcium carbonate. But 1 part of calcium carbonate is equivalent to 0·56 parts of magnesium carbonate.

∴ $4 \times 0{\cdot}56 = 2{\cdot}24$ *parts of magnesium carbonate in* 100,000 *of water*, or $\frac{7 \times 2{\cdot}24}{10} = 1{\cdot}5$ grains per gallon.

Magnesium carbonate has been estimated as high as 9 grains per gallon by Wanklyn and Playfair in Sunderland water.

The estimation of *silica* may become of importance, having in view the fact that, as Dr. Tidy pointed out, its presence diminishes the plumbo-solvent action of water. In quantities it may also create gastro-intestinal irritation and diarrhœa.

It generally exists in the form of insoluble silicate of alumina (clay), or of soluble silicate of sodium.

A measured quantity of water, say 500 c.c., is evaporated to a solid residue; this is treated with strong hydrochloric acid, and then well washed with boiling distilled water, when the residue remaining is dried, ignited, and again treated with the acid and washed as before; any residue ultimately left will consist of most—if not all—of the silica originally present in the water, and the white gritty powder of silica (SiO_2) may be dried and weighed.

Sulphates.

Sulphates exist in most waters, especially selenitic* ones, and are either derived from the strata over or through which the water has passed, or from the sulphur contained in organic pollution (urine, &c.). Even the rain water collected in large towns yields small amounts by taking up the sulphurous acid from the smoky atmosphere.

Sulphates sometimes result from the oxidation of metallic sulphides (chiefly iron pyrites), which exist as such in some strata. They mainly exist as calcium and magnesium sulphates, and to a less extent as sodium sulphate; and any of these when present in large amount, tend to cause diarrhœa and dyspepsia in those unaccustomed to their use. Acid sulphates may, moreover, by creating acidity, thus increase the power of water to carry lead in solution.

Waters collected from the lime-stone and dolomite formations always contain a marked quantity of sulphates, but not so the water from the chalk. The sulphates in lime-stone may reach to 20 parts per 100,000, and consist mainly of calcium sulphate; while those of the dolomite consist to a less extent of calcium sulphate, and partly of magnesium sulphate. The sulphuric acid (SO_3) has been found above 100 parts per 100,000 in some exceptional circumstances of deep wells.

The so-called "sewage-fungus" ("Beggiatoa alba") is found where sulphates abound, and as the action of the fungus is to reduce these to sulphuretted hydrogen, there is a consequent production, to a greater or less

* Selenite is a natural foliated or crystallised sulphate of lime.

degree, of the characteristic and offensive odour of this gas.

The Test.—A few drops of the chloride of barium solution and of dilute hydrochloric acid are added to the water in a test-tube, which is then left to stand for a few minutes, when a precipitate of the sulphate of baryta is created with even very small quantities of sulphates.

If a *quantitative estimation* is desired, 70 c.c. of the water should be taken and boiled for a few minutes, after the addition of slight excess of chloride of barium solution and dilute hydrochloric acid. The precipitate created is collected on a small Swedish filter-paper, washed, ignited, and weighed as barium sulphate, the washing of the precipitate being continued until the filtrate no longer gives a turbidity with silver nitrate.

To express the result in the terms of sulphuric acid (SO_3) it is necessary to remember that every part of barium sulphate represents 0·343 SO_3.

Phosphates.

The phosphates found in water are commonly those of potassium, sodium, and ammonia, and their double salts. The presence of these affords corroborative evidence of remote animal contamination; but they may only exist in small amounts in those waters generally used for drinking purposes even when these be dangerously polluted. When this point is considered in conjunction with the facts that most waters contain faint traces of phosphates, that these may also have their origin in strata—chiefly sandstone—permeated, and that they have also been found to be present in-

considerable quantities in some marshy meadows,—their estimation does not at first sight appear to be of great practical value. But there is one important consideration connected with their presence, *i.e.*, that they form food-pabulum for bacteria and fungi, and thus, whatever be their source, they must always indicate great possibilities of danger on this account.

In every case before a test is applied for phosphoric acid, the water should be reduced from a large bulk to a very small one by condensation, and it is even preferable to dissolve it out from the ash by nitric acid.

The Test.—The best test for their presence is the following:—Add a few drops of pure and colourless nitric acid, and then about twice as much of a solution of the molybdate of ammonium, to some of the water in a test-tube, and boil well. If "traces" of phosphates are present a faint greenish-yellow colour appears; if "heavy traces" a yellow precipitate falls in a few minutes consisting of ammonic phospho-molybdate. Results may be, and are sometimes, returned as "traces," "heavy traces," and "very heavy traces," according as a colour, turbidity, or marked precipitate, is produced in fifteen minutes at a temperature of about 80° F.

* Arsenic acid would cause the same reaction. Where necessary, the two can be distinguished by adding a few drops of a solution of silver nitrate:—

Argentic arseniate forms a brick-red precipitate.

Argentic phosphate forms a yellow precipitate.

CHAPTER XIII.

The Solid Residue.

By this term is implied the substances which are held in solution in the water, and which when the latter is evaporated remain behind as a solid residue.

The mineral salts which a water may contain, and which are taken up in its course through or over the strata it comes in contact with, (with the exception of traces of sodium chloride which may be chiefly taken up from the atmosphere) are—if an attempt be made to arrange them in the order of their most general relative frequency of occurrence—the result of a combination of one or more of the following acids and bases:—

Carbonic Hydrochloric Sulphuric Nitric Nitrous Phosphoric Silicic (silica)	and	Calcium Sodium Magnesium Potassium Iron Aluminium (Lead, Copper, or Zinc).

In regard to the principles which guide chemists in the hypothetical association of the acids and bases found in the water, it is assumed that the combination of the bases and acids is governed by their respective affinities; that is the strongest acid is assumed to be combined with the strongest base, due attention being

also paid, however, to the greater or less degree of solubility of the salts,—since it is well known that this exercises a considerable influence on the manifestations of the force of affinity.

The most common combinations (salts) which are held in solution in a water are:—

The carbonates of calcium, sodium, magnesium, potassium, and iron.

The sulphates of calcium, magnesium, and sodium.

The chlorides of sodium, calcium, and magnesium.

The nitrates of calcium, sodium, and potassium.

The nitrites of calcium, sodium, and potassium.

The phosphates of sodium and potassium.

The estimation of the total solids is not by itself of great practical value from a hygienic point of view, though often when we come to incinerate them valuable corroborative evidence of organic pollution is obtained; the important point is to discover the nature of the constituents of "the solid residue"!

A large amount of mineral solids, consisting as it frequently does in this country largely of calcium carbonates (even up to 50 or 60 parts per hundred thousand), is not considered necessarily injurious; but if a goodly proportion of this is found to be contributed by the salts which form permanent hardness, as indicated by the soap test, one is disposed, since these salts are productive of considerable digestive disturbances in some people, to look with disfavour upon a water containing more than 10 parts per 100,000 of them.

Another important question which a large amount of total solids would give rise to, is that of the suitability of the water for washing and cooking purposes, on account of its hardness being probably excessive.

The total solids have been estimated even above 300

parts per 100,000 in deep well water from the chalk, and sea water contains over 3000 parts per 100,000.

Apparatus required:—

1. A small copper water-bath.
2. A water oven.
3. A platinum dish capable of holding a little over 100 c.c. of water (say 125 c.c.).
4. A desiccator.
5. A weighing apparatus. Oertling's No. 3 balances (Townson and Mercer's catalogue) have been found very suitable to all requirements by the writer.

The Process.

If it is required to estimate the total solids, *i.e.*, the dissolved and suspended, the sample of water should be shaken up; but if the dissolved alone are required, the suspended matters must of necessity be allowed to subside, or which is less desirable, be separated by the process of filtration; but since it is rare that the sample may not in spite of everything contain some of the lighter suspended matter, it would be more accurate to shake the sample, at once remove 100 c.c., and let the estimated solids include both dissolved and suspended matters. When such a course is pursued, however, the fact must be noted, for, as generally performed, it is the total solids *in solution* which are returned as estimated, and such a signification must be attached to the expression "total solids" throughout this book.

1. 100 c.c. of the water are measured out and emptied into the platinum dish, which is then placed upon the water-bath and covered by a glass bell-jar; provision is best made for the escape of steam when the small ringed

water-bath is employed, by making a small dent up the side of the platinum dish, so that it shall not fit accurately at this point to the mouth of the water-bath.

2. When the water is evaporated to apparent dryness the gas is turned out, and the dish removed* and placed for a few minutes in the water-oven, in order that the contents ("the solid residue") may be further freed from all traces of moisture.

To save time it is more convenient to evaporate the 100 c.c. to about 10 c.c. over a low gas flame, and *then* transfer to the water-bath, otherwise the process takes about two hours.

3. The dish is removed and then allowed to cool under a desiccator, the covering of which protects against the access of dust, &c.

4. In a few minutes the dish and its contents are weighed, and the difference between this weight and that of the clean and empty dish, represents "the total solids" in 100 c.c. of water.

5. By means of a pair of crucible tongs the dish is next held in the flame of the Bunsen burner and *slowly* heated to dull redness (not bright!), when any organic matter will give evidence of its presence by charring in little specks, or by causing an evanescent discoloured wave to spread over the residue—if small in amount. If large quantities are present, this organic matter, as it is being burnt off, shows blackened patches which slowly disappear, and gives off dark fumes possessing an odour of burnt horn when nitrogenous matter is present, or of burning sugar when the material is purely organic;—or a sulphurous acid smell may rarely

* When recourse is not had to the water-oven, the under surface of the dish must be always carefully wiped dry before the dish and its contents are weighed.

be detected. Marked scintillation is sometimes also perceptible—that is to say tiny sparks are emitted. Eventually nothing remains but clear *white* mineral ash, except where iron or manganese is present, the former imparting a reddish tint, and the latter a green.

6. The dish is allowed once more to cool under the desiccator and is then re-weighed, and the excess of weight over that of the clean and empty platinum dish consists of mineral ash, and represents "the non-volatile solids." It will be shown later that although the residue after ignition consists of "mineral ash," it does not contain the whole of the mineral material originally present, and hence the selection of the preferable term "non-volatile solids."

7. The weight of "non-volatile solids" deducted from that of the "total solids," represents "the volatile solids."

Example.—The clean platinum dish weighs 40·225 grammes.

The dish + the total solids weigh 40·245 grammes.

∴ 40·245 − 40·225 = 0·020 gramme = the total solids in 100 c.c. of water.

But 100 c.c. of water = 100 grammes.

∴ there is 0·020 gramme in 100 grammes.

Or × 1000 = 20 *parts per* 100,000 *of total solids.*

After ignition, the dish + contents weigh 40·24 grammes.

∴ 40·24 — 40·225 = 0·015 gramme = "the non-volatile solids."

∴ there is 0·015 gramme in 100.

Or × 1000 = 15 *parts per* 100,000 *of* "*non-volatile solids.*"

The total solids = 20 parts and the non-volatile solids = 15.

$\therefore$ 20 — 15 = 5 *parts per* 100,000 *of "volatile solids."*

(Not more than 1·5 parts per 100,000 are volatile in the purest waters).

For public health purposes it must be extremely rare, in view of the information which is acquired in other steps of the analysis, that an analysis of the ash is either necessary or desirable; so that its introduction here would be going beyond the important issues of the subject. It may be pointed out, however, that a few drops of hydrochloric acid will, by creating little or much effervescence, roughly detect the proportion of carbonates present; and that warm distilled water will mostly dissolve from the residue, the salts of the alkalies and of magnesia, sulphate of calcium, &c.; and that the insoluble residue will consist generally in the main of calcium carbonate, but also if present, silica, alumina, phosphates of calcium, peroxide of iron, &c.

A sample of water collected at full tide from the Thames Embankment, showed the following constitution of its total solids:—

Organic matter	3·75
Calcium and magnesium carbonate .	11·5
Calcium sulphate	4·0
Alkaline chlorides	10·35
Alkaline nitrates	1·7
Alkaline sulphates	0·75
Silica and alumina, &c. . . .	0·45
	32·50

A short table for analytical purposes given in the appendix, would be of service in making such an examination of a water residue when desired,—as it sometimes is in the case of mineral medicinal waters and those used for commercial chemical purposes; the table

has been more especially compiled to meet these purposes.

Notes upon the Process.

It has been already seen that by evaporating over the water-bath the process proceeds gently, and the platinum dish and its contents are only exposed to the temperature of boiling water.

Although it may seem desirable to take in every case as large a bulk as 100 c.c. of water, 50 c.c. will often suffice for practical sanitary purposes, the difference being so slight that it does not affect the conclusions drawn. The larger bulk, moreover, entails a prolongation of the time required for complete evaporation to be effected, so that the organic matter which under any circumstances suffers some loss is liable to have this loss increased, and greater opportunities are also afforded to suspended matters in the atmosphere to gain access—unless special precautions in this direction be taken as by the employment of a bell-jar; moreover, so far as the process of weighing is affected by the less and more delicate amounts to be weighed, the scales recommended are so sensitive as to make this a consideration of no import.

As a rule, however, it is preferable to select 100 c.c., and the extra time taken in the evaporation is a matter of little import, since other steps in the analysis may be proceeded with in the meantime. In those cases where it is desired to make the estimation more rapidly, the bulk of the water may be almost completely evaporated by the application of the direct flame to the under surface of the platinum dish, care being taken that the liquid does not reach the boiling point; the dish is then

transferred to the water-bath and evaporation is there completed.

If it is required to make a rough estimate of "the mineral solids" care must be had to remove the dish from the flame *immediately* any evidence of organic matter has disappeared, and not to conduct the incineration at a higher temperature than is found absolutely necessary—or there is a considerable loss in the mineral residue by destruction, dissipation, and volatilization.

Of what may "the volatile solids" consist? *i.e.*, to what may be due the loss by ignition? Such loss is most generally from the following ingredients:—Ammonia salts, destructible organic matter, nitrates and nitrites, some of the chlorides, combined carbonic acid, and the water of hydrated salts (such as calcium sulphate) which thereby become anhydrous, &c.

A platinum dish is cleansed after use with a little dilute hydrochloric acid, then well washed in pure water, and finally heated to redness in the Bunsen flame. It should be allowed to cool upon a clean porcelain slab.

Opinions to be formed upon the amount estimated.—This has already been discussed, and has been seen to depend chiefly upon the nature of the constituents which go to form the total solid residue.

CHAPTER XIV.

Hardness.

The estimation of "hardness" is more of economic concern than of hygienic, since the main consideration which it affects is either that of the amount of soap and time wasted before a lather is formed, or whether the amount of lime salts (which chiefly create the hardness) is such as to render the water unsuitable for some trade processes.* Further, a hard water when used for personal ablution is often found deleterious to delicate skins; it does not extract the same amount of strength from coffee, tea-leaves, and meat substances used for making soup, stews and gravies, as softer water; and vegetables boiled in it lose much of their flavour and colour. On the other hand moderately hard waters are always more palatable than the very soft ones.

It must not be thought, however, that "hardness" in a water is a factor which can be altogether disregarded in a public health sense, for gastro-intestinal derangement, of a nature varying with the constitution of the salts which form the "hardness," may follow the constant ingestion of a hard water in those constitutionally susceptible. As will be seen the "permanent hardness" is generally mainly due to sulphates, and these have an aperient action, so that when they exist in large amounts

* For trade processes generally—apart from the waste of fuel and danger occasioned by the "crust" which hard waters yield to boilers—it is of great importance to the process itself that the water should be moderately soft.

the water is recommended and used medicinally on account of this property. Epsom, Leamington, Scarborough, and Cheltenham provide such waters.

Finally hard waters, from the deposit they yield to boilers, are more apt to be the cause of explosions in these receptacles than other waters.*

The factors which commonly cause "hardness" in a water are the following:—

Calcium and magnesium salts (*i.e.*, carbonates, sulphates, chlorides and nitrates).

Free carbonic acid in the water.

Iron and alumina.

"The total hardness" in most of the drinking waters of this country is created by calcium and magnesium salts, and free carbonic acid; and more especially is such hardness due to calcium salts. Waters, therefore, from the chalk, oolite, limestone, dolomite, and new red sandstone formations—which strata consist largely of various proportions of these several salts of calcium and magnesium—will be those which furnish the highest degrees of hardness.

Of the calcium and magnesium salts, the carbonates very greatly predominate as the cause of "hardness." The carbonates of calcium and magnesium as such, being almost insoluble in pure water, would not create such "hardness" were it not for the fact that they are held in solution by carbonic acid—in the form of bicarbonates.

* The order in which the salts are deposited is the following:—

The carbonates of calcium and magnesium.

The sulphates of calcium and magnesium.

Salts of iron, as bases or oxides, when present.

The silica and alumina when present.

It is calculated that $\frac{1}{4}$ inch of the incrustation—which is a bad conductor of heat—causes the waste of 45 per cent. of coal.

Assuming a water to have its "total hardness" built up of all the materials above enumerated, then if it be well boiled some of these become precipitated, and being no longer in solution they cease of course to add to its "total hardness"—the amount thus lost is accordingly termed "temporary hardness" and that remaining "permanent hardness."

Of what does this "temporary hardness" consist—or in other words what materials are precipitated by the boiling? Foremost in importance is the fact, that the carbonic acid which held the carbonates of calcium and the magnesium in solution is dissipated, so that these insoluble salts fall to the bottom.* Other constituents, however, which were held in solution by the free carbonic acid present, in the form of bicarbonates, are also precipitated—such as iron (the hydrated ferric oxide being formed). Phosphate of lime, and the sulphate if present in large quantity, would also be precipitated.

The "permanent hardness," then, consists of what still remains in solution, *i.e.*, calcium and magnesium sulphates, chlorides and nitrates, a little iron, and any alumina present. A little of the magnesium carbonate thrown down by the boiling will, moreover, become redissolved and hence go to help in the formation of "permanent hardness."

Although the amount of mineral solids which the water contains generally forms an index to the extent of "hardness,"—the latter increasing pretty much *pari passu* with the former—yet this must not be considered as by any means as constantly the case, and some saline waters yielding considerable quantities of "total solids"

* Water containing calcium carbonate in solution, even at ordinary temperatures, will lose some of its carbonic acid and deposit calcium carbonate if exposed to the atmosphere.

are very "soft,"—as seen notably in the case of some Artesian well waters, in which considerable quantities of the bicarbonate of soda exists and mainly contributes to the softness.

This carbonate of sodium is frequently taken up by water in percolating chalk and sandstone strata, in fact it exists in greater or less quantities pretty generally in different waters.

Quantitative Test.

Apparatus required.—

1. A small glass stoppered bottle (of about 250 to 500 c.c. capacity is a convenient size) used for shaking up the water and soap solution.
2. A burette graduated in cubic centimetres and parts of cubic centimetres.
3. A glass beaker, with tripod, wire gauze, and triangle lined with pipe-clay.
4. A measuring flask for 100 c.c.
5. A measuring flask for 250 c.c.
6. Filtering apparatus.

Chemical reagents. 1. A solution in dilute alcohol of soft soap (or as Wanklyn recommends of Castille soap), made to such a strength that 1 c.c. will exactly precipitate either 1 milligramme of calcium carbonate, or those other soap-destroying agents in the water to an extent which is equivalent to 1 milligramme of calcium carbonate.

2. Pure powdered oxalate of ammonia.

The Process.

The *rationale* of the process is as follows:—The soap employed is a result of the combination of an alkali with

one or more of the fatty acids, *i.e.*, oleic, stearic or palmitic. If potash is the alkali employed the result is "soft soap," consisting chiefly of oleate of potassium; whereas if it be sodium a "hard soap" results, consisting mainly of stearate of sodium. Supposing, as in this test, "soft soap" be added to water which contains calcium and magnesium salts in solution, then the fatty acids (oleic mainly) will decompose these salts and combine with the calcium and magnesium, forming chiefly an insoluble oleate of these bases, *i.e.*, calcic and magnesic oleate; and thus the soap has to be added until there is no longer any calcium and magnesium salts to decompose and combine with, when it remains in solution and creates a lathering when the water is well shaken up with it. Hence the more calcium, magnesium, &c., salts there are present, the larger amount of soap solution will be required to decompose them, and in consequence, the longer will the production of a lather be delayed—until in some cases so much precipitate of these insoluble salts has been thrown down, that their very presence alone will in itself delay, or even prevent altogether, the formation of such a lather which is subsequently described as characteristic.

1. 100 c.c. of the water are placed within the "shaking bottle."

2. The burette is then filled up to the 10 c.c. mark with the soap solution, of which 5 c.c. are run into the bottle—when a cloudy precipitate of insoluble calcic and magnesic stearate, oleate and palmitate is formed. The bottle is then briskly shaken to see if its contents will form a lather.

3. The solution is afterwards added in cubic centimetres, and the bottle well shaken up after each fresh addition, until a certain definite and characteristic lather is at last produced.

Many books upon "hygiene" simply state that this lather "must be permanent for five minutes," without giving the student any clue as to the amount, &c., of lather which may be judged sufficient. It would be perfectly true to maintain, for instance, that where so much soap solution has been added that the lather reaches almost to the stopper of the bottle, this requirement has been met, since the lather is "permanent for five minutes;" and there is latitude for error even when it is stated that the lather should be a thin one. I have made it a practice, therefore, to teach that sufficient soap solution has been added, when the conditions created in the contents of the shaking bottle are the following:—

4. (*a*) The contents of the bottle on being shaken must give only a faint dull soft sound.

(*b*) There should be a quarter inch of fine uniform lather.

(*c*) After shaking small particles of the lather must cling to, and slowly descend the sides of the bottle.

(*d*) An unbroken surface of lather must be present after five minutes—which it invariably will be if the above three points are observed.

5. From the number of cubic centimetres of soap solution required for the 100 c.c., the amount of calcium carbonate, or its equivalents in soap-destroying powers, in the water, is deduced.

6. A deduction of 1 c.c. from the amount of soap solution used must be made in every case, however, since this amount of soap solution is required to create a similar lather in the same bulk of *distilled* water, which is of course free from any of the ingredients which are here considered as creating "hardness."

Example.—100 c.c. of water required 15 c.c. of the soap solution to create the characteristic lather.

Deduct 1 c.c. which would be required for 100 c.c. of distilled water = 14 c.c.

But 1 c.c. of the soap solution will combine with 1 milligramme of calcium carbonate, or its equivalents.

Therefore 14 c.c. has combined with 14 milligrammes of calcium carbonate, &c.

Therefore the "total hardness" in 100 c.c. of the water is equivalent to 14 milligrammes of calcium carbonate, and 14 milligrammes in 100 c.c. (or 100,000 milligrammes) = 14 parts per 100,000 (or $\frac{7 \times 14}{10} = 9{\cdot}8$ grs. per gallon).

Conclusions to be drawn from the amount estimated.—The "total hardness" of a water should not exceed 30 parts per 100,000, or it becomes unsuitable for washing and cooking purposes; and if it much exceeds 40 it is practically useless in this respect. A very soft water may contain up to 8; a soft water from 8 to 12; a rather hard water from 15 to 20; a hard water from 20 to 30; a very hard water from 30 to 40 and upwards.

Notes.—Where the hardness exceeds 20 parts per 100,000, so much precipitate of calcium and magnesium stearate, palmitate, and oleate, is created, that it interferes with the formation of a characteristic lather, and leads to an error by over-estimation of the "hardness." In these cases it is necessary to dilute the water with an equal amount of distilled water, *i.e.*, 100 c.c. of distilled water are added to 100 c.c. of the sample, and in the estimation of the hardness 2 c.c. are deducted from the soap solution used up, instead of 1.

The soap solution is unstable, and after several weeks

loses in strength and deposits a thin sediment, which should not however be disturbed: to avoid error therefore, it must always first be standardised when an interval of a week has elapsed since it was last used. This may be most readily done by dissolving, as Wanklyn suggests, 1·11 grm. of pure fused chloride of calcium in a litre of distilled water; the standard solution will then contain chloride of calcium corresponding to 1 milligramme of calcium carbonate to each cubic centimetre. If the soap solution does not register correctly with this, it must be diluted or fortified according to circumstances. A quicker, though rougher plan, but one which will suffice in many cases, is to standardise from the laboratory tap-water if the hardness of this is known and remains approximately constant.

When the results are expressed in "degrees" upon Clark's scale, 1 degree (Clark) simply corresponds to 1 grain of calcium carbonate per gallon in this country, *i.e.*, of 1 part of $CaOCo_2$ in 70,000. In France, however, a degree signifies 1 part of $CaOCo_2$ in 100,000; and in Germany 1 part of CaO in 100,000.

The "total hardness" being found, the next step is to estimate the "temporary" and the "permanent hardness."

1. 250 c.c. of the water are measured out and poured into a glass beaker, which is placed upon a tripod, and protected by wire gauze and triangle lined with pipe-clay from direct access of the Bunsen flame beneath.

2. The water is then boiled for about half-an-hour.

3. After the water has been placed aside and allowed to cool, all the calcium and magnesium carbonate, and most of the iron, will constitute the precipitate notice-

able at the bottom of the beaker—but a little of the magnesium carbonate will have become re-dissolved. It is the supernatant fluid which contains the "permanent hardness," the "temporary hardness" which has been separated being represented by the deposit. In testing for "permanent hardness," therefore, it is necessary to preclude all possibility of any of the precipitated material gaining access to the supernatant water.

4. From the beaker the cooled water is gently returned to the measuring flask, great care being taken to disturb the precipitate (which is left behind) as little as possible. The water is then made up to its original bulk by filling up to the 250 c.c. mark with distilled water, and the loss by evaporation during the boiling is thus made good.

5. 100 c.c. of this water is then filtered through a fine filter paper and tested for its "hardness" in the same manner as the original water was, and this will now constitute the "permanent hardness."

6. If the "permanent hardness" be then subtracted from the "total," the remainder will represent the hardness separated by the boiling, *i.e.*, the "temporary hardness."

Example.—The 100 c.c. of water, thus treated, required 7 c.c. of soap solution.

Deduct 1 c.c. as that used up by an equal bulk of distilled water = 6 c.c.

But 1 c.c. of soap solution is equivalent to 1 milligramme of calcium carbonate.

∴ 6 c.c. of soap solution is equivalent to 6 milligrammes of calcium carbonate.

∴ 6 milligrammes of calcium carbonate represent the permanent hardness of 100 c.c. (*i.e.*, 100,000 milligrammes) of water, or indicate that there are 6 *parts per* 100,000 *of* "*permanent hardness.*"

The total hardness was 14 parts per 100,000 ∴ the "*temporary hardness*" = 14 — 6 = 8 *parts per* 100,000.

Conclusions to be drawn from the amounts estimated:—The greater the proportion of "temporary" to "permanent" hardness the better, since while the former is remediable by several efficient processes—and notably Clark's—the latter in addition to being constituted of more objectionable salts from a health standpoint, is extremely difficult to remedy; although such a process as Howatson's effects something in this direction by adding caustic soda, which by decomposing the earthy sulphates removes so much of the "permanent hardness" as is thereby created. It is accordingly agreed that the "permanent hardness" in a good water should not exceed 7 parts per 100,000.

If it be desired to know the amount of *hardness due to magnesium salts* in a water, where the "total hardness" is known to be due to calcium and magnesium salts and free carbonic acid, it is necessary to precipitate all the calcium salts by a little powdered oxalate of ammonia, and having effected this to filter through double filter papers, until a little of the filtrate when treated with some fresh oxalate of ammonia, gives no evidence whatever of calcium being longer present; then the amount of soap solution (minus 1 c.c.) required to create the characteristic lather will represent the hardness due to magnesium salts, and this deducted from the total will give the hardness due to calcium salts. The difficulty which arises here is to know how much oxalate of ammonia to add, since while it is imperative to supply the necessary amount required to combine with *all* the lime present (so as to form a white precipitate of the insoluble oxalate of lime) yet a marked excess will itself create some degree of "hardness." The best course to pursue

is to add different quantities to equal bulks of water in three Nessler glasses, and to judge from these the minimum amount necessary to create the maximum amount of precipitate; but the glasses should be allowed to stand for some time before comparing, since the precipitate after a while deepens slowly.

Wanklyn has pointed out that whereas lime reacts immediately upon solution of soap, magnesia requires the lapse of time; and that one equivalent of magnesia consumes as much soap solution as one and a half of lime.

If magnesium salts exist in *quantity* in the water the lather is also modified in other directions, a thin fine dirty film forms upon the surface, which soon breaks up, and which cannot be mistaken for the typical lather. In these cases the water must be diluted considerably with distilled water.

Bearing in mind, then, the longer time taken for magnesia to react, the presence of this film will warn the operator that he must proceed slowly and shake more thoroughly—the while he adds the soap solution.

Note.—In Clark's process lime is added in quantities corresponding to the hardness of the water—in order that it may combine with the carbonic acid which holds the calcium and magnesium carbonates in solution, and the whole be precipitated as insoluble calcium and magnesium carbonates. It is difficult day by day, in many cases, to estimate and apply the exact amount of lime necessary to effect this, and the result is that when added, as it sometimes is, in too large quantities, some of it remains in solution in the water in an uncombined state (there being no more carbonic acid to combine with it). Since this is to an extent injurious to the water from a health point of view, frequent at-

tempts should be made to discover this state of things in water treated by Clark's process. A ready and simple method of detecting uncombined lime is by adding a few drops of a solution of silver nitrate to some of the water in a test-tube, when if such be present, the cloudiness created, instead of being white and clean (from the silver chloride), becomes dirty and brown (an oxide of silver being formed).

Soap solution for the estimation of hardness.—Castille soap (which contains about 60 % of olive oil) is frequently used, and if 10 grammes of this be added to 1 litre of weak alcohol (35 % in distilled water), the standard soap solution will be of the strength that 1 c.c. = 1 milligramme of calcium carbonate. When, however, soft soap is employed, 17 grammes of this must be thus dissolved. In every case care must be had that *all* the soap is thoroughly taken up.

The Rivers Pollution Commissioners in their sixth report give the following classification of waters as to their softness:—1. Rain water. 2. Upland surface water. 3. Surface water from cultivated land. 4. River water. 5. Spring water. 6. Deep well water. 7. Shallow well water. And they found that the following formations almost invariably furnish hard waters:—1. Calcareous silurian. 2. Calcareous Devonian. 3. Mountain limestone. 4. Calcareous rocks of the coal measures. 5. New red sandstone. 6. Conglomerate sandstone. 7. Lias. 8. Oolites. 9. Upper greensand. 10. Chalk.

CHAPTER XV.

Examination of the Sediment.

Chemical.—Since the estimation and examination of the total solids have only included those solids which are in solution, it will be desirable in some instances to make a chemical examination also of the sediment. In these cases it is necessary to collect a fair quantity of this deposit; and the most simple method by which this can be effected, and one which will also be found in every way very satisfactory, is to remove as much as possible by a pipette, and then place it into a small conical glass (fig. 22), to which a cover is subsequently applied; after about an hour the supernatant water can be sufficiently closely decanted off without disturbing the material which has settled. The sediment can then be collected on filter paper, and well washed with pure water, dried, and the organic matter then carefully burnt off at as low a temperature as possible; the residue is next boiled with about 100 c.c. of distilled water (to which a little dilute hydrochloric acid has been added) and if any part then remains undissolved, it should be treated with strong nitric and hydrochloric acids together.

All the residue having been thus rendered soluble, it may be tested in the wet by the analytical table given in the appendix,—where in those rare cases such a procedure may be thought desirable for hygienic purposes.

Where, however, a sediment forms from the sample of water, any analysis which fails to take advantage of

the important positive evidence which a *microscopic examination* affords, will exhibit a great short-coming—since this alone in some cases may suffice to condemn a water, by detecting elements which, though denoting danger, have not been shown to be in suspicious amounts by the other steps of the analysis. It is mainly, after all, the *nature* of the organic matter which denotes present danger, and by a microscopical examination of the water direct evidence of this can in many cases be acquired. Some of the sediment, then, should be collected from the beaker in which it has been allowed to settle since the commencement of the analysis, by means of a small pipette, in the manner adopted with urine sediments. It is then transferred

FIG. 27.—Wynter Blyth's tube for collecting sediments.

to several glass slides, cover-glasses are applied, and the examination by the microscope commenced; any excess of water upon the slide being removed by clean blotting paper.

Wynter Blyth's tube is a convenient instrument for collecting water sediments; as seen in the accompanying figure, it is similar in appearance to a huge pipette which is capable of holding about a litre of water. A small glass cell fits over the small lower extremity of the tube, into which the deposited matter collects after a time. By the insertion of the long rod-shaped stopper, the cell and the sediment within it can easily be removed undisturbed.

The various forms of animal and vegetable life, and

of inanimate organic and inorganic material, are best sought after by commencing with the 1 inch power, next passing on to the $\frac{1}{4}$ inch power, and then prosecuting the examination further by means of the $\frac{1}{12}$ inch oil immer-

FIG. 28.—Showing the sediment of a pond-water, a sample of which was collected in the early spring (× 250). Drawn by A. E. Evans, M.B.

1. A desmid.
2. Tabellaria floccosa (Diatomaceæ).
3. Actinophrys.
4. A confervoid growth.
5. A vegetable fibre showing spiral cells.
6. Silicious particles.
7. Conferva.
8. Gomphonema.

Various forms of minute unicellular plants are seen scattered about the "field."

sion lens and an Abbé's condenser. Further steps are necessary in the examination of bacteria, for which the reader is directed to the section written by Dr. Boyce.

If the suspended matter is so light that it will not settle, drops of the water must be examined; but it must be extremely rare that any visible suspended matter does not deposit in part after an hour or two.*

Before giving a list of animate organisms which the naked eye or microscope may disclose, it must be pointed out that these do not (with few exceptions) convey danger in themselves, but that it is rather their presence which implies such danger—denoting as it does that some pabulum, and possibly a dangerous one, accompanies them, upon which they are capable of feeding and existing. Though this pabulum may be vegetable organic material, or its products—as it frequently is, since they mostly exist in stagnant pond water in greatest numbers—the presence of these organisms in abundance, bearing as they do a direct and constant ratio to their food supply, will be often sufficient in itself to condemn the water as containing at least an injurious amount of vegetable pollution. The fact that animal and vegetable life have powers of purifying the water is beside the question of a sanitary analysis, their very presence denotes impurity, and with the attainment of purity they mostly disappear.

The higher and macroscopical types of animal life, such as water-fleas, water-bears, amphipoda and isopoda, &c., broadly speaking denote less danger than the lower and more minute forms (bacteria, amœbæ, infusoria; but all alike will of course yield evidence of organic impurity by Wanklyn's method.

The most suspicious elements are those which point

* A slight mineral sediment may often be increased by boiling the water—when sand, chalk, &c., get deposited. If a water be a markedly chalk one, the chalk will carry down with it some also of the suspended animal and vegetable matter.

directly to sewage contamination, and next to these those which point indirectly to such contamination. The latter will be found in hair, wool, cotton and linen fibres, reddish-brown globular masses, &c., the former in those objects enumerated on page 138.

A careful examination, however, should always be made for further evidence of danger, as afforded by the presence of bacteria, fungi, amœbæ, anguillulæ, and ova, &c., of the various animal parasites; for each of the first four classes of organisms, apart from the inherent danger of some of them, certainly point to the presence of further impurities (other animal matter, &c.) which form their favourite food pabulum; and the dangers of parasitic infection are too well appreciated to need insistence upon here.

Matter which may be Found by a Microscopical Examination of Water.

I. Inanimate.

(*a*) *Mineral.*—Sand and flint particles generally have a sharp and angular outline, though often somewhat rounded from rolling and attrition.

Clay and marl (alumina-silicate) particles are amorphous, and very minute.

Chalk particles are likewise amorphous, mostly somewhat larger than those of clay and marl, and generally rounded in outline. A drop of hydrochloric acid placed beneath the cover-glass dissolves them, *i.e.*, causes them to disappear with effervescence.

Iron peroxide forms a reddish-brown amorphous debris, soluble like the chalk in hydrochloric acid, and

blued when a drop of the solution of ferrocyanide of potassium is allowed to run under the cover-glass.

Mica forms thin fine films of very irregular outline.

(*b*) *Vegetable.*—Vegetable debris and parenchymatous cells; the dotted ducts of the vessels; spiral vessels, or spiral fibres drawn out of the cells; pieces of the cuticle with the vegetable "hairs" still adhering; pollen.

Woody fibres; fragments of leaves, &c.

Starch cells, of wheat, potatoe, &c.

Macerated paper.

Vegetable matter may also appear as dark flattened structureless masses (opaque), or most frequently only as debris—when the diagnosis is attended with great difficulty: if, however, any spiral vessels, or fibres, or dotted ducts can be distinguished, these will always point to the nature of any ulterior debris, &c., with which they may be associated.

Dark masses from soot may be present in the water.

(*c*) *Animal.*—Hairs; feathers; down.

Wool, silk, linen, or cotton fibres.

Striped muscular fibres; fat cells and crystals; connective tissue; epithelial scales; shreds of mucous membrane.

Scales from the Lepidopterous insects (moths, &c.), and wings, legs, &c., of other insects.

Reddish brown globular masses are sometimes justly attributed to sewage pollution.

II. Animate.

(*a*) *Vegetable.*—Minute forms of vegetable life mostly belong to the class of cryptogamous (*i.e.*, non-flowering) plants, and all—except diatoms and bacteria—contain

chlorophyll, and are in consequence green. They may be divided into:—

1. *Small and microscopic fungi*, which, with moulds, represent the lowest forms of vegetable parasites. They may be present as spores, sporangia, or as mycelium.

Both bacterium termo and sarcina ventriculi present familiar instances of these forms.

Beggiatoa alba has been badly named "the sewage fungus," but any water containing sulphates is capable of supporting the fungus, quite independently of the source from which such sulphates are derived.

2. *Numerous forms of algæ*, ranging in size from those only visible by high microscopic powers, to those visible with the naked eye. Of these there are many families:—the volvocineæ, of which volvox is the type, comprise the lowest vegetable forms of minute unicellular organisms; the oscillatoria (*vide* plate iii.) exhibit a pendulum like motion; the confervaceæ (*vide* plate iii.), &c.

Protococcus pluvialis is an interesting instance of an algoid plant which can live in the atmosphere, and which is often found in pure rain-water.

Bacteria, desmids, and diatoms, would all be included in this class, the characteristic feature of the two latter being the fact that they are built up of two precisely similar parts. The algæ when in considerable quantities give a dark green repulsive appearance to the water, and may create diarrhœa, and when they die and decay the water acquires an offensive taste and smell; otherwise they are not of much hygienic importance.

(*b*) *Animal*:—1. *Protozoa*. (*a*) Rhizopoda. Amœba will be recognised by its characteristic amœboid movement. Actinophrys is another common and familiar form; and polyps shows a very low type of structure. In

spongilla fluviatilis (the fresh water sponge) the animal substance is spread over a network of spicules.

(*b*) Infusoria. Paramœcium, vorticella, coleps, and euglena viridis, are all common types.

Stentor is among the largest of this class, and is so named from the trumpet-like shape of the body.

2. *Cœlenterata.*—Hydra is a common type of this sub-kingdom.

3. *Annulosa.*—This sub-kingdom embraces:—

(*a*) Crustacea including the Amphipoda* Isopoda† and Branchiopoda‡.

Both cyclops quadricornis and daphnia pulex are familiar types of this class: in the latter the antennæ act as oars and propel the little animal through the water by a series of short springs or jerks; they assume a red colour in summer, and when in swarms they give a bloody tinge to the water.

(*b*) Arachnida, including water bears (the tardigrada), &c.

(*c*) Insecta. Either in the larval, pupal, or adult forms.

4. *Annuloida.*—This sub-kingdom embraces the scolecida, and includes turbellaria, rotifera (or wheel-animalcules) taeniada, næmatoidea, anguillulæ (water-worms).

5. *Molluscа.* Including polyzoa, siphonida, &c.

The various *parasites* which may be conveyed through the medium of drinking water are:—

The tape-worms (Taenia Solium, T. Mediocanellata,

* The Amphipoda are sessile-eyed malacostracans. Their bodies are compressed laterally, the eyes are immobile, and their feet are directed partly forwards and partly backwards.

† The Isopoda possess sessile eyes and a depressed body, and the feet are of equal size and move in the same direction.

‡ The Branchiopoda are so-called because their branchiæ or gills are situated on the feet. The head is not distinct from the thorax, which is much reduced in size.

T. Echinococcus, and Bothriocephalus Latus); the Guinea-worm (Dracunculus Medinensis); small leeches (Hirudinidæ); the Round-worm (Ascaris Lumbricoides); the Thread-worm (Oxyuris Vermicularis); Bilharzia Hæmatobia; Dochmius Duodenalis; Tricocephalus Dispar (the Whip-worm); Filaria Sanguinis Hominis; Distomum Hepaticum (the Liver-fluke of sheep).

All these may be found in either embryonic or adult stages of development.

From out of this confusing mass of objects what material may be selected as affording direct evidence of human sewage contamination? *i.e.*, which are those objects which can rarely, except along with sewage, gain excess to the water? They are either (1) substances which from their indigestibility commonly leave the body in the fæces; (2) substances which may do so when digestion is interfered with; or (3) the various animal parasites which infest the human gastro-intestinal tract.

Under the first heading would be embraced such substances as:—various connective tissue elements, fat cells and crystals, muscle fibres, some vegetable cells and starch grains, &c.

Under the second heading shreds of mucous membrane, mucus, epithelial cells, gall stones, quantities of all kinds of food in a semi-digested state, &c.

The third heading includes T. Solium, T. Mediocanelata, Bothriocephalus Latus (either as eggs, segments, or the adult form); Ascaris Lumbricoides; Oxyuris Vermicularis; Tricocephalus Dispar.

(Bacterium Termo and Sarcina Ventriculi are vegetable).

CHAPTER XVI.

Gases in Water. The Opinion upon a Water Analysis.

It is a generally known fact that water can absorb almost all gases or vapours coming in contact with it, and this with great readiness—for it is the aeration of water which gives to it the pleasant taste and sparkling appearance. The absence or degree of this aeration, however—as has been already pointed out—affords no evidence of the water's purity or impurity, since the foul water of a shallow polluted well is generally markedly aerated, whereas the pure water collected from great depths in the chalk (notably in the case of many artesian wells) is sometimes poorly so. The best waters are invariably well aerated; those from the chalk and limestone formations contain much carbonic acid and little or none of any other gas, and where the water from these strata has been subjected to conditions of very high pressure and low temperature, carbonic acid may even be in such quantities as to give a turbid appearance to the water, when this is first exposed to the air. A water thus naturally highly charged with this gas is the well known Apollinaris water, and it may be interesting to point out in this connection that some of the carbonic acid present in water may be derived from the oxidation of organic matter (carbon), though of course it always mainly indicates a decomposition of carbonates.

In addition to the innocuous gases upon which the aeration of a pure water depends, *i.e.*, nitrogen, oxygen, and carbonic acid, it is obvious that water may at the same time take up noxious gases (such as the constituents of coal gas), or those which, though not noxious in themselves, yet—inasmuch as they are generally the products of organic putrefaction and decomposition—indicate the presence of danger, such as sulphuretted hydrogen, ammonias, marsh gas (CH_4) and olefiant gas (C_2H_4), &c.

Some waters issuing as springs in the vicinity of volcanoes, are charged with sulphurous acid.

The estimation of the nitrogen, oxygen, and carbonic acid, can serve no practical hygienic ends, as no conclusions of value can be drawn from the results; interesting as they are from a chemical point of view. Evidence of most of the other gases may be obtained by heating the water to 110° F., in the manner already described when treating of "smell;" or frequently sulphuretted hydrogen and ammonium sulphide may be discovered in very small quantities by the addition of a solution of lead acetate, when the water darkens. A solution of the nitro-prusside of sodium (a few drops) will create a violet purple colour with ammonium sulphide, but will remain unchanged if sulphuretted hydrogen be alone present.

Should, however, a more careful and delicate investigation be desirable, the gases may be liberated by boiling half a litre of the water, and then collected over a mercurial trough, when they may be tested for their nature according to the methods given in the chapter upon air-analysis.

Though ammonia will always exist in small quantities, when there is marked evidence of its presence, or when

sulphuretted hydrogen, ammonium sulphide, or the constituents of coal gas are present, then the water should be regarded with the greatest suspicion.

While sulphuretted hydrogen may, however, be derived from mineral sulphides, or from reduction of mineral sulphates* (which reduction is frequently effected by organic matter and living algæ), and the presence of ammonia may be due to reducing agents in the strata subsequently percolated acting upon nitrates, yet these sources are very rare as compared with the danger yielding ones.

With regard to vapour in water, advantage can be taken of the fact that if water is distilled the foreign liquids present will come over in the first quantities of distillate, and this may accordingly be examined for any suspected vapours.

Analysis of Mineral Waters.

In these waters a careful analysis of the ash must be made, and the following acids and bases should be especially sought for :—

(a) Bases.—Potassa, soda, lithia, baryta, strontia, magnesia, alumina, protoxide of iron and also of manganese.

(b) Acids.—Phosphoric, sulphuric, silicic, carbonic, boric ; chlorine, bromine, iodine, sulphuretted hydrogen.

* Good examples of waters charged with sulphuretted hydrogen from such harmless sources, are to be found at Harrogate and Aix-la-Chapelle notably. Some waters from the clay have a distinct odour of sulphuretted hydrogen, derived from the tiny particles of iron pyrites which enter into the composition of the clay.

Specimens of the water at various depths in the case of wells should be collected.

The whole of the dissolved gases must be collected and analysed.

The temperature of an immersed thermometer (at the time of collecting) should also be taken, and the specific gravity should be ascertained and compared with that of distilled water taken as 1000.

The Opinion upon a Water Analysis.

It will be seen from what has already been written, that there are many considerations to be carefully weighed together, before any definite opinion can be formed upon the presence or absence of organic pollution in any given water sample; and in order to impress the point, the reader is again reminded of the fact, that in forming such an opinion dependence must not be placed upon the issue of any one stage of the analysis, but upon the results of the various stages considered collectively.

To instance the force of this contention it is only necessary to point out, that in some country districts, if reliance were placed upon Wanklyn's process alone, the rain-water even would be held to be suspicious.

There is no necessity, however, in those cases where it is necessary to form a *rapid conclusion* as to whether a water may be safely drank for the time being, to subject it to a complete and thorough analysis; since the quantitative estimation of the "two ammonias," the chlorine and the nitrates, together with a qualitative examination for nitrites and the poisonous metals, will here suffice.

It is desirable that a water analysis should be

as inclusive and complete in every case as it is possible to make it, and it becomes an absolute *sine qui non* that this *shall* be so in those instances when the question arises of selecting a water from among several others for a permanent domestic supply.

In expressing an opinion upon the analysis, it is very desirable to adopt such terms which, while leaving no doubt in the mind of anyone as to the opinion held upon the safety of the water, shall not be *too* definite in signification: and thus it will always be better to say that "the water shows no evidence of harmful organic pollution," than to employ such a precise statement as "there *is* no organic pollution;" and the results of a single examination in the case of well, river, and pond water, must not be considered sufficient evidence to enable one to pronounce aught but the fact, that *the sample* examined is that of a good water. In order to commit oneself to a statement which would imply that the source from which the water is derived is a *constantly* pure one, it will be necessary to examine many samples at different seasons, and under different conditions of rainfall, drought, &c.—any of which furnish important factors in determining the different degrees and characters of the fouling which may obtain. It would be of great assistance to most medical officers of health if they carefully constructed "water standards" for their districts. Such would be prepared by selecting the *purest* water in each locality, and would form a ready and reliable means of detecting the smallest amount of additional impurity which may have gained access to the supply of any particular household, the water of which it may be desirable to examine. For instance, a water sample may well contain 2·5 parts per 100,000 of chlorine without any suspicion being aroused; but say

that the average of the pure water of the locality is 1·5 parts, then the excess becomes important evidence of "added chlorine," the presence of which would have to be accounted for.

It will be appropriate here to recapitulate the amounts which, when found in the most important stages of the analysis of water, would indicate danger, or make its employment otherwise undesirable.

"*Free*" *ammonia and* "*albuminoid*" *ammonia.*—If the "albuminoid" ammonia exceeds 5 parts per hundred million, the "free" should not be above this amount, but if the former is represented by a cypher, then considerable "free" ammonia may not signify danger; conversely the "albuminoid" ammonia may reach to 10 parts per hundred million if the "free" does not exceed 1.

The oxidisable organic matter examined by Tidy's modification at 80° *F.*—The oxygen absorbed must reach the proportions of 160 parts per hundred million in 2 hours, or about 400 parts per hundred million in peaty waters, before its amount can be regarded as suspicious.

Chlorine.—More than 3 parts per 100,000, if not accounted for by the strata permeated, would arouse distrust.

The oxidised nitrogen.—More than 0·1 parts per 100,000 of nitrogen in nitrates and nitrites, excites suspicion. The faintest trace of nitrites will generally condemn.

The poisonous metals.—More than $\frac{1}{20}$ grain of lead or copper should probably suffice to condemn. Zinc should not exceed $\frac{1}{4}$ grain, nor iron $\frac{1}{2}$ grain. The faintest trace of arsenic condemns.

The total solids.—These should not exceed 50 parts per 100,000, but of course much depends upon their constitution. In no case, except in peaty waters, should

there be much charring on ignition, nor should fumes or odour ever be appreciable during this process.

The hardness should certainly not exceed 30 parts per 100,000, and the greater the proportion of "temporary" to "permanent hardness" the better.

CHAPTER XVII.

WATER SAMPLES.

Sample I.

A VERY PURE WATER.

(*i.e., Showing amounts which, when not exceeded, denote great purity in all the steps of the analysis*).

Physical Characters.—Pleasant taste. Well aerated. Clear and bright. No marked colour. No smell. No sediment.

Reaction	Neutral.	
Saline Ammonia	2	parts per 100,000,000.
Organic Ammonia	4	
O_2 absorbed from Permanganate (in 2 hours at 80° F.)	40	
Total Solid Matters	8	parts per 100,000.
(*a*) Volatile	2	
(*b*) Fixed	6	
(*c*) Appearance on ignition	No appreciable blackening. No smell or fumes given off.	
Total hardness	8	
(*a*) Temporary	5	
(*b*) Permanent	3	
Chlorine	1·5	
Equivalent to Common Salt	2·4	
N as Nitrates and Nitrites	0·01	
Poisonous Metals	*nil*	grains per gallon.

Microscopical Examination of Sediment. If any sediment it must be very small in amount, and should consist of a harmless mineral or unrecognisable debris.

Note.—As has been pointed out, if the oxidisable organic matter is of a vegetable nature, the 40 parts per hundred million may be much exceeded in even a very pure water.

Sample II.

A Foul and Dangerous Water.

(i.e., Showing dangerous pollution in all the steps of the analysis).

Physical Characters.—Unpleasant taste and smell (on heating). A dirty (yellow or brown) colour. Turbidity. Sediment. Often poorly aerated.

Reaction	Alkaline.	parts per 100,000,000.
Saline Ammonia	10	
Organic Ammonia	12	
O_2 absorbed from Permanganate (in 2 hours at 80° F.)	over 250 (if not due to peaty matter).	
Total Solid Matters	60	parts per 100,000.
(*a*) Volatile	25	
(*b*) Fixed	35	
(*c*) Appearance on ignition	Considerable charring, and fumes and odour may be given off.	
Total hardness	30	
(*a*) Temporary	15	
(*b*) Permanent	15	
Chlorine	8	
Equivalent to Common Salt	13·1	
N as Nitrates and Nitrites	0·5	
Poisonous Metals	Dangerous amounts of Pb, Cu, or Zn.	grains per gallon.

Microscopical Examination of Sediment:—Low forms of animal and vegetable life, such as bacteria and fungi; and organic debris. Evidence of human excretal contamination in epithelium, cotton fibres, undigested particles, paper, &c.

Notes.—Water polluted by sewage *emanations* (gases and vapours) shows an absence of this excess of chlorine and nitrogen as nitrates and nitrites; but other evidences of organic pollution are marked, and especially the "free ammonia." Microscopically, abundant evidence of bacteria and micrococci is forthcoming.

Sample III.

A Suspicious Water.

(*i.e., Showing amounts which indicate danger in all the steps of the analysis. The possibility of peat and of certain mineral elements having been yielded by the strata being excluded*).

Physical Characters.—Slightly coloured (shades of yellow or brown). Not perfectly clear. No marked taste or smell, though not palatable. Slight sediment.

Reaction	Alkaline.	parts per 100,000,000.
Saline Ammonia	6	
Organic Ammonia	11	
O_2 absorbed from Permanganate (in 2 hours at 80° F.)	over 160	
Total Solid Matters	40	parts per 100,000.
(*a*) Volatile	15	
(*b*) Fixed	25	
(*c*) Appearance on ignition	some charring, no fumes or smell.	
Total hardness	25	
(*a*) Temporary	15	
(*b*) Permanent	10	
Chlorine	4	
Equivalent to Common Salt	6·5	
N as Nitrates and Nitrites	0·25	
Poisonous Metals	*nil* (except faint traces of iron).	grains per gallon.

Microscopical Examination of Sediment. A few low forms of animal and vegetable life, of questionable origin and significance.

Sample IV.

Rain-Water.

(*As collected generally in country districts*).

Physical Characters—No colour apart from that of pure water. Quite clear. Pleasant taste. No smell. Well aerated. No sediment.

Reaction	Slightly alkaline.	
Saline Ammonia	5	parts per 100,000,000.
Organic Ammonia	0·5	
O_2 absorbed from Permanganate (in two hours at 80° F.)	about 15	
Total Solid Matters	3·5	parts per 100,000.
(*a*) Volatile	1·5	
(*b*) Fixed	2	
(*c*) Appearance on ignition	no charring, &c.	
Total Hardness	1	
(*a*) Temporary	0·4	
(*b*) Permanent	0·6	
Chlorine	0·5	
Equivalent to Common Sal	0·8	
N as Nitrates and Nitrites	0·005	
Poisonous Metals	*nil*	grains per gallon.
Microscopical Examination of Sediment.	—	

Notes.—In towns the reaction is slightly acid, from the sulphurous acid in the atmosphere; and the water is a little different in other respects, owing to further impurities taken up, such as soot—which furnishes other sulphur compounds and increases the amount of "free ammonia."

That rain-water, which is collected in country districts after long periods of continuous rainfall, affords the purest possible *natural* water.

Sample V.

A Typical Peaty "Upland Surface" Water.

Physical Characters.—The colour is generally yellowish-brown, but peat may create various shades of green, yellow, and brown,—or there may even be no colour at all. Not quite clear (from fine suspended matter). No marked taste or smell. Aeration slight.

Reaction	Distinctly acid.	
Saline Ammonia	1·5	parts per 100,000,000.
Organic Ammonia	12	
O_2 absorbed from Permanganate (in two hours at 80° F.)	about 300-400	
Total Solid Matters	8	parts per 100,000.
(*a*) Volatile	5	
(*b*) Fixed	3	
(*c*) Appearance on ignition	Some blackening, faint sweet odour	
Total Hardness	5	
(*a*) Temporary	1	
(*b*) Permanent	4	
Chlorine	1	
Equivalent to Common Salt	1·6	
N as Nitrates and Nitrites	0·009	
Poisonous Metals	*nil*	grains per gallon.

Microscopical Examination of Sediment.—Shows vegetable debris, fibres, cells and parenchyma, and frequently minute forms of vegetable life (*vide* Chapter on Water Sediments).

Note.—In many "peaty waters" the "organic ammonia" and the "oxygen absorbed" will be found to much exceed the amounts given above,—which constitute the mean of many such waters analysed.

Sample VI.

Spring Water from the Chalk.

Physical Characters.—No marked colour. No smell. Very palatable. Well aerated as a rule. Quite clear. No sediment.

Reaction	Alkaline.	
Saline Ammonia	1	parts per 100,000,000.
Organic Ammonia	3	
O_2 absorbed from Permanganate (in two hours at 80° F.)	about 65	
Total Solid Matters	30	parts per 100,000.
(*a*) Volatile	6	
(*b*) Fixed	24	
(*c*) Appearance on ignition	no charring, &c.	
Total Hardness	20	
(*a*) Temporary	13	
(*b*) Permanent	7	
Chlorine	2·5	
Equivalent to Common Salt	4·1	
N as Nitrates and Nitrites	0·4	
Poisonous Metals	*nil*	grains per gallon.
Microscopical Examination of Sediment.	—	

Note.—The solid constituents of such waters must naturally vary materially in different samples.

Sample VII.

A Typical River Water.

(*Derived from deep springs, direct rainfall, and surface drainage*).

Physical Characters.—No marked colour. Fairly well aerated. Pleasant taste. No smell. Clear and no sediment—or a very slight one.

Reaction	Faintly alkaline.	
Saline Ammonia	1·5	parts per 100,000,000.
Organic Ammonia	6	
O_2 absorbed from Permanganate (in two hours at 80° F.)	about 80	

Total Solid Matters	25	parts per 100,000.
(*a*) Volatile	8	
(*b*) Fixed	17	
(*c*) Appearance on ignition	No, or extremely faint, discoloration	
Total Hardness	21·5	
(*a*) Temporary	13	
(*b*) Permanent	8·5	
Chlorine	1·7	
Equivalent to Common Salt	2·8	
N as Nitrates and Nitrites	0·2	
Poisonous Metals	*nil*	grains per gallon.

Microscopical Examination of Sediment.—A trace of mineral or vegetable debris may be present.

Notes.—These quantities will also be found to approximate to the averages of the water supplied by the Thames Companies (*i.e.*, after it has passed through their filters).

The composition of River water will always of course vary with the following circumstances.

1. The nature of the country through which the river courses, and which it therefore drains; *i.e.*, whether this be cultivated and manured, or wild; whether there be much or little vegetation; and whether it be thickly or sparsely populated.

2. The amount of pollution by sewage, waste products of manufactories, the drainage of manured land and cemeteries.

3. The nature of the bed of the river, and of the strata through which the springs (which feed the river) rise.

4. The rapidity and smoothness of flow—*i.e.*, the more rapid and interrupted this is, the greater the powers of the river in the direction of self-purification.

Sample VIII.

A Deep Well-Water from the Chalk.

Physical Characters.—No marked color. Pleasant taste. No smell. Generally well aerated—though sometimes poorly so, and at others to great excess. Clear. No sediment.

Reaction	Alkaline.	
Saline Ammonia	8	parts per 100,000,000.
Organic Ammonia	3	
O_2 absorbed from Permanganate (in two hours at 80° F.)	about 75	
Total Solid Matters	45	
(*a*) Volatile	10	
(*b*) Fixed	35	
(*c*) Appearance on ignition	no charring, &c.	
Total Hardness	29	parts per 100,000.
(*a*) Temporary	19	
(*b*) Permanent	10	
Chlorine	4·5	
Equivalent to Common Salt	7·4	
N as Nitrates and Nitrites	0·5	
Poisonous Metals	*nil*	grains per gallon.
Microscopical Examination of Sediment.	—	

Note.—The total solids may reach as high as 250 parts per 100,000 in some of these waters, but this amount is very rare.

Sea-Water.

The Rivers' Pollution Commissioners found that sea-water contained approximately:—

	Parts per 100,000.
Free Ammonia	0·006
Chlorine	1975·6
Total Solids	3898·7

A specimen collected by the late Dr. Tidy during high water at Margate gave :—

Chlorine	1770·5
Total Solids	3343·0
Lime	35·1
Magnesia	205·6
Silica	0·4
Hardness	564·0

Sewage.

An average composition of sewage was found, by the above mentioned Commissioners, to represent about the following quantities in parts per 100,000.

Free Ammonia	5·520
Nitrogen as Nitrates and Nitrites	0·003
Chlorine	10·66
Total Solids	72·2

Scheme for Effecting an Analysis in the Quickest and Most Convenient Manner.

(As by this scheme more than one process is going on at the same time, care must be taken that all due attention is given to each; although a little confusion may be experienced at first, yet, after a little practice, the plan will be found as practical as it is expedient).

1. Remove 100 c.c. of the water from the sample bottle, and start the evaporation over a water-bath for "the total solids in solution." This will take from 2 to 3 hours.

2. Remove 250 c.c. and commence the estimation of "the oxidisable organic matter."

3. Remove 500 c.c. from the bottle, and start the

distillation for the estimation of "saline" and "organic" ammonia.

4. Well shake the sample, noting any smell distinguishable, and decant about 1 litre of the water into a clean glass beaker; cover this, place aside, and allow the bulk of any suspended matter present to settle—with this object disturb the water as little as possible when amounts are removed for the following purposes.

5. Estimate the hardness, "total," "temporary," and "permanent."

6. Make the "quantitative estimation of chlorine."

7. Test for poisonous metals, and estimate quantitatively if any one is present.

8. Note the physical characters in the two-foot tube &c., together with the reaction of the water (acid, alkaline, or neutral).

9. Test qualitatively for nitrites; sulphates; and phosphates.

10. Collect aud make a microscopic examination of the sediment (if any).

11. Prepare the water for the quantitative estimation of "nitrogen as nitrates and nitrites," set aside, and complete the process on the following morning.

Scheme for Examination Purposes.

(In the examination for Public Health Degrees, the time is limited, and—as they are at present conducted—the subjoined tests are considered to suffice in detecting whether the candidate has a good knowledge of the subject of water analysis or not. He is expected to hand in an abstract of each process by which he arrives at his results, in addition to the results themselves).

1. Start the quantitative estimation of "free" and

"albuminoid" ammonia* and then proceed to determine the following points :—

2. The physical characters *i.e.*, colour; clearness; aeration; reaction; taste; smell; sediment (if any).

3. The quantitative estimation of chlorine.

4. The total hardness.

5. The qualitative examination for poisonous metals and calcium salts.

6. The qualitative examination for nitrates; nitrites; sulphates; and phosphates.

7. The macroscopic appearances of any sediment present.

8. If the necessary material is given to the candidate, and only one sample is provided for analysis, a quantitative estimation of "nitrogen in nitrates and nitrites," and of the "oxidisable organic matter," would be required. (*Vide* Appendix for a quick method of estimating the former).

An Analytical Form.

(*Adapted to a quick analysis of a mineral residue*).

If a solid residue:—(1) Dissolve as much as possible by boiling in distilled water; (2) dissolve any residue by boiling in dilute hydrochloric acid; (3) dissolve any residue still remaining by warming with strong hydrochloric acid and nitric acid, mixed in the proportion of 2 parts to 1.

An entire solution having been thus effected, to some of the liquid add :—

A. A few drops of **hydrochloric acid,** until the maximum precipitate—if any—is created.

* This process must be watched as the other tests are proceeded with. A skilful worker will have finished step 4 before the "free" ammonia is all over, and ready for estimation.

(*a*) *A white precipitate* = silver, mercury (*-ous* salt), or lead; *add ammonia*, if the precipitate dissolves = silver; if it blackens = mercury; if unchanged = lead.

Add a solution of *potassium chromate* to some of the original liquid:—a reddish brown precipitate = silver; a red precipitate = mercury; a yellow precipitate = lead.

B. If *no* precipitate add **strong sulphuretted hydrogen water.**

(*a*) *A yellow precipitate* = Arsenic, tin (*-ic* salt), or cadmium. If arsenic or tin (*-ic*), the precipitate is soluble in ammonium sulphide and in liquor potassæ. Distinguish by Reinsch's test. If cadmium the precipitate is more of an orange colour, and it is insoluble in ammonia sulphide and liquor potassæ.

(*b*) *A red precipitate* = antinomy.

Add liquor potassæ to original liquid, and a white precipitate forms, soluble in excess.

(*c*) *A brown precipitate* = Bismuth, copper, or tin (*-ous*).

If bismuth or copper, the precipitate is insoluble in ammonia and liquor potassæ.

If tin (*-ous*), the precipitate is soluble in ammonia and liquor potassæ.

Copper will give a bronze colour and precipitate with potassium ferrocyanide.

(*d*) *An orange or black precipitate* = Mercury (*-ic*, salt).

A solution of potassium iodide will give a red colour to the original liquid.

C. To a fresh portion of the solution add a solution of the **chloride of ammonium, and ammonia.**

(*a*) *A black precipitate* = iron;—ferrocyanide of potassium will yield a blue color; ferricyanide of potassium, a red with ferr*ic* and blue with ferr*ous* salts.

(*b*) *A greenish-white precipitate* = aluminium.

(*c*) *A dark green precipitate* = chromium.

D. If no precipitate, further add some **ammonium sulphide** solution.

(*a*) *A white precipitate* = zinc.

(*b*) *A salmon-colour precipitate* = manganese.

(*c*) *A black precipitate* = nickel or cobalt.

If nickel, liquor ammoniæ yields a blue; if cobalt, liquor ammoniæ yields a green.

E. If no precipitate, add **ammonium carbonate** solution.

(*a*) *A white precipitate* = barium, strontium, or calcium.

If barium—burns with a green flame; if strontium and calcium—burns with a red flame; potassium chromate creates a yellow with strontium, and none with calcium.

F. If no precipitate, is obtained by this stage, only magnesium, ammonium, potassium, and sodium can be present.

Add liquor potassæ.

(*a*) *A white precipitate* = magnesium.

If *no precipitate*, but ammonia is evolved = ammonium.

If potassium, it burns with a lilac flame; if sodium, it burns with a yellow flame.

Potassium and ammonium will create a yellow with platinum chloride solution.

For acids.

A. Add **barium chloride solution** (or if silver, mercury, or lead be present, use barium nitrate).

(*a*) *A white precipitate* = sulphates, carbonates, phosphates, oxalates,* or borates.

Add *hydrochloric acid*.

If sulphates,† the precipitate is insoluble even on

* If organic matter has not been previously destroyed.

† Insoluble sulphates will not have much concern for sanitarians, but barium and lead sulphates may be detected by converting them

boiling; if carbonates the precipitate is soluble (also in acetic acid) with *effervescence*; if phosphates or borates the precipitate is soluble (also in acetic acid); if oxalates the precipitate is soluble (but not in acetic acid).

B. If no precipitate, to some of the original solution add ***silver nitrate.***

(*a*) *A white precipitate* = chlorides or cyanides*; add ***nitric acid.***

If chlorides the precipitate is insoluble, (and it *fuses* on heating); if cyanide the precipitate is soluble on boiling.

(*b*) *A pale yellow precipitate* = bromides or iodides; add a drop of strong ***sulphuric acid.***

If bromides, starch paper is coloured orange; if iodides, starch paper is coloured blue.

C. **Test especially for:**—Nitrates; sulphides—heat with acid and sulphuretted hydrogen evolved; acetates*—heat with dilute sulphuric acid (vinegar smell); tartrates*—heat with strong sulphuric acid it blackens *immediately*, and burnt sugar odour and sulphurous acid smell evolved; citrates*—treated similarly to tartrates, blackens *slowly* and pungent irritating fumes are given off.

Salicylic acid.—Add a solution of the perchloride of iron, and a deep purple colour is created.

Boracic acid and *borates.* Condense the liquid by evaporation from a large bulk to a very small one, then add hydrochloric acid and continue the evaporation. While this is proceeding direct a flame across the top of the

into their corresponding sulphides, by heating them with sodium carbonate upon charcoal, and the metals can be detected by their blow-pipe reactions.

* If organic matter has not been previously destroyed.

evaporating dish, and it will acquire a green tinge. Or evaporate the liquid to near dryness, and then add about a drachm of spirit of wine, warm together and then ignite, and observe a bright green flame.

After adding just sufficient hydrochloric acid to render the liquid slightly acid, dip in a piece of turmeric paper, then dry this at a gentle heat, and it will turn red.

Alkalimetry and Acidimetry.

For estimating the amount of alkalinity or acidity of a liquid, it is expedient to use standard test solutions based on the atomic system. Of such, a "normal solution" signifies one made up as follows:—The number representing the atomic weight of the reagent employed is found, and then, whatever this may be, a corresponding number of grammes of the reagent are weighed out and dissolved in a litre of water—in the case of univalent substances (H = 1), such as sodium, iodine, &c.; but the number is divided by 2, in the case of bivalent substances, such as lead, calcium, &c.; and by 3, in the case of trivalent ones. "Seminormal" and "decinormal" solutions are obviously those made up to $\frac{1}{2}$ and $\frac{1}{10}$, respectively, of the strength of the "normal" solutions.

In estimating alkalinity, a standard solution of hydrochloric acid is employed; whereas for acidity, a standard solution of sodium carbonate is taken.

The normal solution of hydrochloric acid (HCl)—since the atomic weight of H = 1 and Cl = 35·37—consists of 36·37 grammes of hydrochloric acid to a litre of distilled water.

The normal solution of sodium carbonate (Na_2CO_3)—since the atomic weight of Na = 23, C = 12, and O = 16—consists of $\frac{106}{2} = 53$ grammes of pure sodium carbonate to a litre of distilled water.

A similar amount of each of these solutions should thus exactly neutralise each other; but it is difficult to get these to absolutely correspond, and when they do not do so, the difference must be ascertained, and a

simple calculation made in order to get their relative values.

In making the estimation methyl-orange (about 1 gramme to the litre) is the "indicator" which should be selected. This substance has the property of yielding a beautiful scarlet colour in the presence of acidity; but its solution, which is of a bright orange colour, must not be employed where organic acids are concerned, or where nitrites are present.

Example.—It is desired to estimate the alkalinity of a solution. A few drops of the methyl-orange "indicator" are run into a measured quantity—say 100 c.c.—of the solution in a Nessler glass, placed upon a white porcelain slab.

A "decinormal" solution of hydrochloric acid is then dropped in from a graduated burette, until a scarlet tint appears, denoting all alkalinity to be neutralised.

It took 20 c.c. of the decinormal hydrochloric to effect neutrality, therefore the alkalinity is equivalent to 20 c.c. of this acid solution. But 20 c.c. of the "decinormal" hydrochloric acid is equivalent to a similar amount of "decinormal" sodium carbonate solution, therefore the alkalinity is equivalent to 20 c.c. of the "decinormal" sodium carbonate solution.

But 1 litre of the "normal" solution contains 53 grammes of sodium carbonate; therefore 1 litre of the "decinormal" solution contains 5·3 grammes of sodium carbonate, and 1 c.c. of the "decinormal" solution contains 0·0053 gramme of sodium carbonate, and 20 c.c. of the "decinormal" solution contains 0·106 gramme of sodium carbonate.

Therefore the alkalinity of 100 c.c. of the solution is equivalent to 0·106 gramme of sodium carbonate.

In testing for acidity, the "indicator" would be

added, and the sodium carbonate "decinormal" solution run in until the scarlet colour is just discharged, when the calculation would be made upon the principles shown above.

TABLE OF ATOMIC WEIGHTS (*by latest researches*).

Barium	(Ba)	=	136·8
Calcium	(Ca)	=	39·9
Carbon	(C)	=	11·97
Chlorine	(Cl)	=	35·37
Copper	(Cu)	=	63·18
Iron	(Fe)	=	55·88
Lead	(Pb)	=	206·4
Magnesium	(Mg)	=	23·94
Hydrogen	(H)	=	1·0
Nitrogen	(N)	=	14·01
Oxygen	(O)	=	15·96
Sodium	(Na)	=	22·99
Sulphur	(S)	=	31·98
Zinc	(Zn)		64·9

A QUICK METHOD OF ESTIMATING THE "NITROGEN IN NITRATES."

The phenol-sulphuric acid method of estimating nitrates is not quite as delicate as the copper zinc couple process, but the results can be very much more rapidly arrived at. It will not be necessary here to go fully into the details of the process, if the main principles are pointed out, since the former will occur to the reader of the foregoing pages.

The **reagents required** are:—

(1) Phenol-sulphuric acid, made by mixing 8 vols.

and 1 vol. respectively, of pure sulphuric acid and pure phenol, heating for several hours at 100° C., and then diluting to three times the original bulk with distilled water.

(2) A standard solution of potassium nitrate (0·7215 gramme to the litre), each c.c. of which contains 0·01 milligramme of nitrogen.

(3) Liquor potassæ.

The Process.

10 c.c. of the water sample and 10 c.c. of the standard nitrate solution are each placed in a clean platinum dish, and evaporated just to dryness. 3 c.c. of the phenol-sulphuric acid, followed by a couple of drops of pure hydrochloric acid, are then run into both of the dishes, which are subsequently allowed to remain on the water bath for about three minutes.

The contents of the two dishes are then each put into a separate Nessler glass, and the dishes are washed out with liquor potassæ (the washings of each being also placed into its appropriate Nessler glass) and then liquor potassæ is added to each glass until effervescence ceases. The glasses are then filled up to their marks with distilled water. That which received the contents of the platinum dish which held the 10 c.c. of standard nitrate solution, has now assumed a distinct orange colour (due to the formation of tri-nitro-phenol, *i.e.*, picric acid); and the contents of the other Nessler glass are coloured, more or less, according to the amount of nitrates in the 10 c.c. of water sample.

By transferring measured quantities from the deeper coloured liquid (which will generally be that containing

the potassium nitrate), into other Nessler glasses, which are again filled up with distilled water to their marks, a match is effected; that is to say, it is learnt how much of the deeper coloured liquid is required, when this is filled up to the 50 c.c. mark with distilled water, to match the tint created by those nitrates which are furnished by the water sample in the other Nessler glass.

Suppose that 25 c.c. are required of the 50 c.c. of the darker coloured liquid (which in this case contains the 10 c.c. of standard nitrate solution). Then of course ($\frac{1}{2}$ of 10 =) 5 c.c. of the standard solution are required, to match the colour created by nitrates, in the 10 c.c. of water sample.

But 1 c.c. of the standard solution contains 0·01 milligramme of nitrogen; therefore 5 c.c. of the standard solution contains 0·05 milligramme of nitrogen; therefore there is 0·05 milligramme of "nitrogen in nitrates" in 10 c.c. (10,000 milligrammes) of water, or there is 0·5 milligramme of "nitrogen in nitrates" in 100,000 milligrammes of water, or 0·5 part per 100,000.

PART II.

SOIL EXAMINATION.

The Analysis of Soils.

The Sanitarian will not often find it necessary to make a chemical analysis of soil, and where he does, it must be very rarely required that the analysis should proceed beyond a qualitative estimation of those various constituents which are soluble in water, and which may, on this account, gain access in many cases to the drinking water supply. If, moreover, the subject is looked upon from an agricultural point of view, the soluble constituents of the soil will alone concern the analyst, since these alone are taken up by plant life. It will be necessary, however, to include in the analysis those substances which are soluble in a weak acid medium, since such acidity is sometimes naturally supplied in the form of vegetable and peaty acids, carbonic acid, &c. A quantitative estimation of any of these substances is of little practical import, and no attempt will be made to treat of such, since the reader will have already become familiar with the chief methods of quantitative analysis which would apply to such an estimation. All soils contain, though in different proportions, the chief mineral constituents which are found in the ash of the plants which grow upon them; and an analysis of such ash will afford a rough and ready clue to the constitution of the soil, which may frequently suffice for all practical purposes; but it should be pointed out in this connection,

that the same value is not attached to an analysis of the aqueous extract of soils as was formerly the case, for it is now well understood that such does not contain the same proportions of the soluble constituents as originally existed before the solution was made. This is accounted for by the fact that soil will yield up readily to water, the substances in regard to which its powers of absorption have been satisfied, while it will more or less strongly retain other soluble ingredients. Whereas the power of absorbing and retaining moisture is a consideration of the first importance from a health view,—exercising as it does an important influence upon the health of whole communities,—yet it is of little practical value to perform any tests in this direction upon small quantities of soil, which are collected and brought to a laboratory: the powers of retaining moisture,—together with other conditions,—are so largely dependent upon the characters of the subsoil, &c., that the most reliable and valuable information is always obtained, by observations of such tests as are applied by nature herself to the soil *in situ*.

In collecting samples, it must be borne in mind that the characters of the soil may vary within small areas, and at different depths—so that many samples must be collected and analysed, before one can speak, with anything approaching accuracy, of the constituents of the soil of a *district*. The depth of the surface soil varies considerably in different localities. In uncultivated grounds the soil generally occupies only a few inches in depth on the surface, and in cultivated grounds its depth is generally the same as that to which the implements used in cultivation have penetrated. Soil is composed of certain mixtures or combinations of the following substances:—the earths—silica, alumina, lime and mag-

nesia; the alkalies—soda, potassa and ammonia; the acids—sulphuric, hydrochloric, carbonic, nitric, phosphoric and silicic; oxide of iron, and small portions of other metallic oxides; a considerable proportion of moisture; and several gases,—chiefly oxygen, hydrogen and carbonic acid. Besides these, every soil contains a large amount of vegetable and animal matter, which is either partially or wholly decomposed.

The stratum which lies immediately under the soil is called the *subsoil*, into the composition of which comparatively little organic matter enters; sometimes this subsoil is porous sand or gravel; sometimes light and loamy and closely similar to the super-imposed soil; sometimes stiff (clayey) and more or less impervious to water.

The Analysis.—The sample having been collected, the coarser stones should be removed, and all lumps broken up so far as possible with a hard wooden pestle.

Special apparatus has been devised, both for thoroughly crushing, and also—where this is not done—for washing and separating the various coarse constitutents seriatim; thus the small rock fragments are first separated, then the small stones or gravelly sand, next the coarse sand, the fine sand, and the clayey sand, until finally the finest clayey portions only remain.

But essentially the analysis is of importance in detecting the substances which a water will extract and hold in solution, and hence this is made the chief feature of the analysis here.

Schulze's method is the best for thus obtaining the aqueous extract of a soil:—the necks of several middle-sized funnels are closed with small filters of strong filter paper; these are moistened, and the paper pressed close to the sides of the funnel; the air-dried soil is then

introduced in small lumps ranging in size from a pea to a walnut, (but not pulverised or even crushed), until the funnels are filled to about two-thirds. Distilled water is now poured in, in quantity sufficient to cover the soil; if the first portion of the filtrate is turbid, it must be poured back into the funnel, and the filtration allowed to proceed quietly; the funnels are again filled with water, and this process of extraction is continued until the filtrates weigh twice or three times as much as the soil used (2-3 litres). The several filtrates are next mixed in one vessel, and a portion of the washed soil is kept. The aqueous solution is divided into a larger and a smaller part, and the larger part is evaporated to a small bulk. A part of this concentrated solution is then tested for organic matter and chlorine; and the remainder, (which generally contains a little precipitate), is evaporated to dryness and cautiously ignited,—so that the organic matter may be slowly but completely burnt off; some of the ash thus obtained is tested in the dry for manganese, by fusing it with 2 or 3 parts of sodium carbonate upon a platinum wire; the bead of manganate of soda thus formed, appears as a transparent green while hot, and an opaque bluish-green when cold. The remainder of the ash is dissolved in hydrochloric acid, when any effervescence indicates carbonic acid; the whole is then evaporated to dryness, —to separate silicic acid—then moistened with hydrochloric acid, water added, and the mixture warmed and filtered. The filtrate is next tested for sulphuric acid, phosphoric acid, iron, and (if required) for magnesia, potassa, soda, and lithia. The residue generally contains a little carbon, a little clay, and also silicic acid; and the silicic acid may be tested for by washing the residue, boiling it with caustic soda, filtering, satu-

rating with hydrochloric acid, evaporating to dryness, and finally taking up the residue with water—when the silicic acid will be left behind.

Alumina was never found by Schulze in the aqueous extract.

The smaller part into which the non-concentrated aqueous solution was divided, is finally tested for nitric and nitrous acids and ammonia. The portion of the soil insoluble in water averages about 90 per cent. of the total, and the analysis then proceeds to deal with this, thus :—

About 50 grammes of the washed soil are heated for several hours with hydrochloric acid (of medium strength) upon a water bath, and then filtered. The filtrate, which is often yellow from ferric chloride, contains the substances in the soil which are soluble in an acid medium; and it is accordingly tested for iron, manganese, copper, alumina, lime, fluorine, magnesia, potassa, soda and lithia, silicic, phosphoric, sulphuric, carbonic, and even arsenic acids.

As the solvents which act naturally on the soil, however, are far weaker than the hydrochloric acid here employed, it will be more exact if we examine those substances which are soluble in carbonic acid water—as by saturating distilled water with carbonic acid, and allowing this to act upon the soil for several days in a closed flask, which should be well shaken from time to time. Water containing both carbonic acid and ammonium chloride (about 0·05 per cent.), should also be allowed in a similar manner to act upon the soil, and the substances *then* taken up should be discovered.

No practical hygienic purpose will be served by analysing that part (which is always the greater) of the soil which is insoluble even in an acid medium,—it then

becomes chiefly a question of finely crushing, and examining for, and estimating, silicates.

An examination for the *peaty acids* may be made thus:—Some of the washed soil is dried and sifted, to separate any straw, roots and stones; what passes through the fine sieve is digested for several hours at 80° to 90°, with a solution of carbonate of soda, and filtered; the filtrate is then slightly acidified with hydrochloric acid,—and if brown flakes separate, these consist of the peaty acids, *i.e.*, ulmic, humic, or geic acids. Collect these flakes upon a weighed filter, wash until the water begins to be coloured, dry, and weigh. Burn the dry mass, deduct the weight of the ash (after subtracting the filter ash) from that of the dry mass, and enter the difference as "acids of humus."

The estimation of the *moisture* of soil has been seen to be of no practical value: as ordinarily performed it is simply a matter of driving off the water from a weighed quantity of soil, weighing the residue, and noting the loss as due to water.

The estimation of carbonic acid is conducted upon lines which will at once occur to the reader.

FIG. 29.—Fraenkel's borer, for taking samples of soil from any depth.

A microscopical examination of the soil may sometimes be made with advantage, and a bacteriological one generally surpasses even the chemical in importance. The microbes in soil, their characters, and what they effect, are as yet but partially understood, and they afford an interesting subject for research.

The results, obtained by the writer, of a mineral

analysis of a few common soils, are here appended; but it must be understood that those soils which are called by the same name, may vary considerably in the nature and amounts of their less characteristic constituents. The main purpose of the following analyses is to afford an *approximate* idea only of the amount of the various substances which enter into the composition of the more common soils.

CLAY *(Stourbridge)*.

Silica	68
Alumina	15
Organic matter	4
Iron (oxide)	3
Lime	1·5
(carbonate 1·4)	
(sulphate 0·1)	
Magnesia, &c.	traces 0·5
Phosphoric acid	
Water	8
	100·0

CALCAREOUS *(Sussex)*.

Lime	90
(carbonate 89·5)	
(sulphate 0·35)	
(phosphate 0·15)	
Magnesia (carbonate)	0·5
Oxide of iron and alumina	2·5
Silica	0·55
Organic matter	3
Water	3·45
	100·00

PEATY *(Devonshire)*.

Organic matter	90·5
Silica	7·5
Alumina	0·74
Lime	0·5
Sulphuric acid	0·2
Oxide of iron	0·46
Magnesia	0·05
Phosphoric acid	0·02
Sodium and potassium	0·03
	100·00

GARDEN VEGETABLE MOULD.

Silica	49·25
Organic matter	13·5
Oxide of iron	9·25
Carbonic acid	7·12
Water	6·9
Calcium	5·13
Alumina	2·74
Sodium and potassium	2·5
Chlorine	1·5
Sulphuric acid	1·3
Oxide of manganese	0·25
Phosphoric acid	0·4
Magnesium	0·16
	100·00

If an attempt be made to classify a soil, it can readily be effected in the following manner. A weighed quantity should be mixed with water, shaken thoroughly, and then placed at rest; in a few minutes the sand will

settle, while the fine lighter particles of clay will remain suspended. If the water and clay is decanted, after a time it becomes clear; and the clay can be collected, dried, and weighed.

Any soil which is not so rich in vegetable matter as to constitute a "peaty" one, and which contains—when thus treated—not over

10 per cent. of clay = a "sandy" soil.
10-40 per cent. of clay = a "sandy loam."
40-70 per cent. of clay = a "loamy soil."
70-85 per cent. of clay = a "clay loam."
85-95 per cent. of clay = a "strong clay soil."

A soil containing no sand at all = a "pure agricultural clay,"—which is essentially a silicate of alumina, mixed with organic matter, alkalies, and oxide of iron.

If there is more than five per cent. of calcium carbonate, the soil is called "a marl;" and if there is more than twenty per cent. "calcareous."

"Peaty" soils generally contain from sixty to eighty per cent. by weight of organic matter; "rich cultivated soils" from about five to twenty per cent.; and "stiff clayey" ones from two to ten per cent.

Strong clays absorb and retain nearly three times as much water as sandy soils, while peaty ones absorb a still larger proportion; and the same remarks broadly apply to the relative readiness with which water is lost by evaporation from those soils through the day, and can be reabsorbed from the air at night.

In 100 parts of soil dried in the air, Krocker found that clayey soils, before manuring, yielded 0·1 to 0·45 of ammonia; loamy soils, 0·13 of ammonia; sandy soils (never cultivated), about 0·05 of ammonia; marls, 0·004 to 0·09 of ammonia.

The various manures with which the soils under cul-

tivation are dressed, of course effect considerable changes in the constitution of the original soil, besides yielding abundance of soluble matter to the water which comes in contact with them. The commoner manures are :—

Farmyard and animal excrement, and "Guano."

Bones, and other phosphatic manures.

Vegetable manures—sawdust, soot, charcoal, peat and seaweed.

Ammonia salts.

Sodium salts—especially the nitrate.

Potassium salts—especially the chloride and phosphates.

Gypsum.

PART III.

AIR ANALYSIS.

CHAPTER I.

The Normal and Abnormal Constituents of Air. Eudiometry.

A hygienic analysis of atmospheric air aims at detecting the injurious gases and vapours which it may contain, together with the nature and amount of the suspended matter present.

Atmospheric air, the elastic fluid which we breathe, consists, almost *in toto*, of a mixture of the gases—nitrogen and oxygen; it is possessed of gravity, fluidity, and of the power of becoming rarified and condensed, and since all gases have now been resolved, by reduction of temperature and increase of pressure, into liquids, they differ only from those bodies in their degree of elasticity, and in the aeriform condition under which they exist.

It is advantageous to recognise this at the very outset, for a knowledge of the fact will serve to make clear a good deal in the methods of treating gases for analytical purposes. We shall find ourselves, for instance, measuring gases in a graduated burette, pouring

them into receptacles, and condensing them in a very similar manner to fluids.

Broadly, the atmospheric air consists of:—oxygen, 21 per cent., and nitrogen 79 per cent.; but to be more correct a trace of carbonic acid has to be included in its composition, which thus becomes:—

Oxygen	20·96
Nitrogen	79
Carbonic acid . .	0·04
	100·00

After this air has been respired, the carbonic acid is increased to the extent of about 4 per cent., and there is a corresponding diminution in the oxygen: *i.e.*, expired air contains about:—

Oxygen	16·96
Nitrogen	79
Carbonic acid . .	4·04
	100·00

and in addition to this change in its composition, it has gained "organic matter," and is saturated with aqueous vapour.

An analysis of ordinary air will detect, however,—in addition to oxygen, nitrogen and carbonic acid,—the presence, in traces only, of suspended matter, and also of other gases. If an attempt is made to represent, in a tabular form, the common constituents of country and town air respectively, the following would have to be included in each case:—

COUNTRY AIR.

Nitrogen	79·00
Oxygen	20·96
Carbonic acid	0·04
Aqueous vapour	variable (from 0·4 to 1·6)
Ammonia	traces
Oxidised nitrogen	,,
Ozone	,,
Marsh gas	,,
Common salt and other mineral substances	,,
Organic matter—in vapour or in suspended solid form—living or dead (including micro-organisms)	,,

TOWN AIR.

(Reaction—faintly acid)	
Nitrogen	79·00
Oxygen	20·92 (average)
Carbonic acid	0·05 (average 0·07 during fog).
Aqueous vapour	variable
Ammonia	traces
Oxidised nitrogen	,,
Sulphurous acid	,,
Sulphuretted hydrogen	,,
Marsh gas	,,
Common salt and other mineral substances	,,
Organic matter—more than in country air (including micro-organisms)	,,

It will thus be seen, that, with the exception of oxygen and nitrogen, everything else which may be found in the general atmosphere exists only in the very smallest proportions, and as it is these latter

constituents which chiefly concern the sanitarian, it will be gathered that any processes adopted for their estimation, must be delicate, and carefully performed, and that large bulks of air should be employed.

There is not, under ordinary circumstances, much to be gained by a sanitary examination of the general "external atmosphere,"* except it be with regard to its moisture, or during the occasion of city fog. The chief scope for such an analysis lies in the unhealthy air of crowded rooms (as to its organic matter, &c.), of manufactories (as to the presence of poisonous gases from the chemicals, &c., employed), of mines (for poisonous and explosive gases), of cellars (for "ground air," "sewer gas," &c.).

What then are the gaseous and volatile substances which may, under favourable conditions, gain access to the air? and what is their source? It is obvious, with regard to the latter question, that their source must be either from the vital processes of organic life (respiration and transpiration), the decomposition of organic matter, the combustion of various materials, or from the products, &c., of trade processes.

They may be thus classified :—

Carbon and compounds of carbon :—Carbon (from incomplete combustion).

Carbonic oxide (from combustion, iron and copper stoves, furnaces, &c., cement works, brickfields).

Carbonic acid (from combustion, brickfields, cement works, respiration, chemical works—soda water manufactories, brewing, &c.).

Carburetted hydrogen (from combustion).

Carbo-ammoniacal substances (from sewers, &c.).

* By the term "external atmosphere" is implied the atmosphere not included within buildings, mines, &c.

Sulphur and compounds of sulphur :—Sulphur (from combustion, &c.).

Sulphurous acid (from combustion—and varying in amount with the pyrites in the fuel, bleaching works, copper smelting, volcanic action, cement works, brickfields, &c.).

Sulphuric acid (from combustion).

Sulphuretted hydrogen (from combustion, brickfields, chemical works, &c.).

Ammonium sulphide (from combustion).

Carbon bisulphide (from combustion, vulcanised india-rubber works, &c.).

Chlorine and compounds of chlorine : — Chlorine (from bleaching works).

Hydrochloric acid (from alkali works, &c.).

Compounds of nitrogen.— Ammonia. Nitrous acid. Nitric acid. (From organic decomposition.) Ammonium sulphide. Ammonium carbonate. (From combustion.)

Organic vapours, the composition of which is undetermined (from decay of organic matter, trade processes — such as soap works, glue refiners, bone boiling and burning, slaughter houses, tanyards, &c.).

Metallic fumes of arsenic (from copper smelting, &c., *vide* arsenic).

,, ,, copper (from copper smelting).

,, ,, lead (from various trade processes).

,, ,, zinc (from brass founding).

,, ,, phosphorus (from match making, especially before the red or amorphous phosphorus was employed).

Water.—(From combustion, respiration, &c.).

The next point is to consider upon what *principles* we

shall proceed to estimate the *proportions* of the constituents of any gaseous mixture,—since the *nature* of these is determined by reactions with which the reader is already familiar. Well! if we follow out the analogy which such a mixture presents to a liquid, some chemical substance might be added—as in the latter case—with which the gas in question has the property of combining, and the amount of such gas which has thus combined may be readily estimated by the increased weight, &c., gained by the substance which was exposed to it. This plan, however, is not very satisfactory, and is not, in consequence, generally employed; the only other practical alternative remaining, is to estimate the amount of gas which has thus been absorbed, by ascertaining what loss in *volume* the original mixture has suffered.

The eudiometer (εὐδία, serene, good, and μέτρον, measure) is the instrument used for conducting the latter process, and it consists of an apparatus employed for measuring the volume of a gas, or gaseous mixture; and eudiometry may be defined as the act of estimating the volumetric proportions of any of the constituents of a gaseous mixture. Eudiometry is the method now in frequent employ; and in order to demonstrate the most simple and ready manner of performing it, the estimation of the amount of oxygen in a sample of air is chosen. It is obvious that the process must be conducted with great care, and that—dealing as we are with a gas—the different volumes of the mixture must be measured off under exactly the same conditions of temperature and atmospheric pressure; and that—varying as these do from time to time—the process of estimation should not be unduly prolonged.

We have seen that the amount of oxygen in the

external atmosphere may be taken to constitute a normal percentage of 20·96. After a careful consideration of the number of investigations which have been made, it seems that it may reach its highest limit of 21 per cent. over large expanses of open country; and that in the most crowded parts of cities it seldom, if ever, falls below 20·75 in the external atmosphere (even in the time of fog), or below 20·65 in the atmosphere of occupied rooms.

In mines,* however, the oxygen has been estimated as considerably below 20 per cent. (Angus Smith found 18·27 per cent.; during fog and frost in Manchester, and in the pit of a theatre, the same observer found 20·89 per cent. and 20·74 per cent. respectively).

Having in view the fact that the amount of oxygen diminishes to such a slight extent in atmospheres which are foul and unhealthy, it is clearly not by the estimation of this element that much information of a sanitary nature can readily be gleaned, and its introduction here is mainly because it serves admirably to illustrate the performance of an eudiometric observation,—the principles of which the reader must early become conversant with. It must not be thought, however, that small though the difference is between 20·96 per cent. and 20·75 per cent., (*i.e.*, 0·21 per cent.), it may be altogether ignored, for the loss in oxygen is made up by some deleterious agent or agents,—and these will be present in a million volumes to the extent of 2,100 volumes!

* The explosion of gunpowder, where this is still employed, further contributes to the carbonic acid yielded by respiration to an atmosphere which is never sufficiently renewed.

The Estimation of the Amount of Oxygen in the Atmosphere by Eudiometry.

Apparatus required.—Many of the gas-measuring apparatus are cumbersome, costly, and difficult to work, and the writer has found one of the most simple and convenient of these instuments to be Hempel's gas bu-

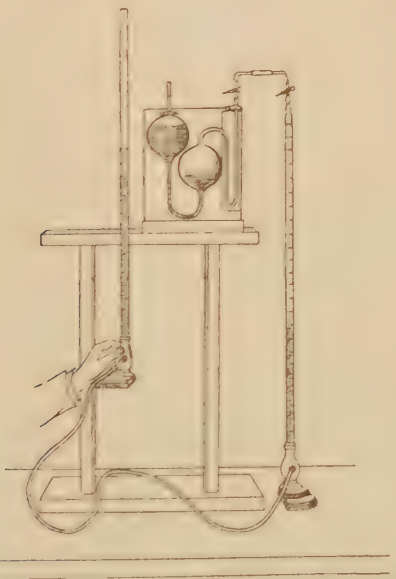


Fig. 30.—Hempel's gas burette and absorption apparatus.

rette. From the accompanying figure, it will be seen to consist of two glass tubes supported on flat round iron stands, and connected together at their lowest points by wide india-rubber tubing; the tube which is seen in the figure to be held up (and which will be sub-

sequently referred to as tube A) is plain, and is continued, full bore, up to its top, where it generally ends in a slight trumpet-shaped mouth; the other tube (which will be referred to as tube B) is graduated into cubic centimetres, and narrowed above so as to fit inside of a piece of small india-rubber tubing, which serves to connect it with the apparatus containing the chemical substances employed to absorb and remove any constituent of a gaseous mixture. This apparatus, as shown mounted upon a wooden stand, consists of two glass bulbs blown in a fine glass tube bent in the manner portrayed in the plate; the lower globe has a larger diameter than the upper, and is capable of holding about 150 c.c. of the reagent employed, while the upper one should be of at least 100 c.c. capacity.

Reagents employed.—A solution of pyrogallic acid and caustic potash in distilled water.

The Process.

1. The amount of atmospheric air is first measured in the gas burette in the following manner:—Both tubes are placed upon a level surface, and water is poured down the plain tube A until each tube is about half full. Now, owing to the well known physical fact that water seeks its own level, according as the tube A is lowered, will the height of the water in B descend, and *vice versâ*. Raise the tube A, therefore, and thus fill the tube B with water; then lower the tube A, and the atmospheric air of the compartment will rush into the graduated tube B, where it is imprisoned by applying a pinch cock to the india-rubber tubing at is mouth. This volume

of air collected is next exposed to the same atmospheric pressure as obtains in the room, by adjusting the two tubes (on wooden blocks), at the respective heights necessary to insure that the water stands at the same height in each. A reading is then made of the volume of air experimented on, by noting the space (*i.e.*, number of c.c.'s) which it occupies in the graduated tube.

2. Connection is then made, as shown in the figure, by fine stiff india-rubber tubing with the "absorption pipette," which is fitted upon a stand and raised up very close to the tube containing the air,—since it is desirable to have as short a length of tubing as possible. The necessary quantity of pyrogallic acid solution is then poured into the "absorption pipette" to quite fill the lower and larger bulb, and the height to which the solution stands should be marked off upon the piece of enamel which is seen to form a background to a part of the absorption apparatus. Next, by liberating the two clasps shown in the figure, the gas burette and absorption pipette are put into communication with each other, and by raising the tube A the water ascends in tube B, and the air is thus forced over into the absorption pipette; whence it can be brought back again by lowering the tube A.

This is slowly repeated several times,—in order to give the solution time to absorb all the oxygen,—and the air is finally drawn back into the burette, care being taken that the acid solution is left standing exactly at its original level, as shown by the mark placed upon the piece of enamel. The height of the water in the two tubes is then brought to the same level, just as it was at the commencement of the process (and for the same reason), and then the volume which the air *now* occupies is read off. The volume remaining is broadly

due to the nitrogen, and the difference between it and the original volume represents the oxygen absorbed.

It is desirable to *further* expose the air to the pyrogallic acid, and then to see if the volume of the remaining gas (N) is the same. If so "a constant reading" has been obtained, and there is no doubt that *all* the oxygen has been absorbed.

Notes upon the Process.

Since, as it was pointed out, the conditions of temperature must remain the same throughout the estimation, the gas burette after it has been charged, should not be handled except by its iron stand.

The solution of acid employed should be made about up to the strength of 15 grammes of pyrogallic acid, and 50 of caustic potash (in sticks).

The oxygen may also be estimated by *Dumas' process*, in which the air having been freed of its carbonic acid by a strong solution of caustic potash, is passed through a combustion tube containing a length of pure spongy metallic copper. The copper is kept ignited, and the air is gradually drawn over the surface of the bright metal which becomes tarnished by oxidation, and the difference in weight of the original copper and this tarnished metal, represents the oxygen taken up from the volume of air experimented upon.

CHAPTER II.

Collecting Samples. Examination by the Senses.

Samples are most conveniently collected in large wide-mouthed, glass-stoppered bottles, of about four litres capacity—which, when used for these purposes, are termed "air-jars." These must be thoroughly cleansed in every case before use—the last washings may with advantage be of distilled water; they are then inverted, allowed to drain quite dry, and subsequently stoppered; and after the collection of the sample the jars should be closely sealed in those cases where they have to be removed. Lastly, a label which carries a written statement of the current temperature and pressure, is applied.

Following out the principles advocated with regard to water samples, a sample of air should be collected—whether it be vitiated by respiration, combustion, trade-processes, or by products of decomposition, &c.—at the time when, so far as can be judged, the atmosphere will afford its maximum evidence of pollution.

In investigating the case of respiratory contamination in the air of a bedroom, for instance, the sample should be taken shortly before the first riser quits the room; that is to say, after the room has been occupied by its customary number of inmates for the greatest consecutive number of hours. Specimens of the external atmosphere are best collected at a height of about four feet from the ground, that being about the mean level at which it is most generally inspired.

The air is made to occupy the jar by either of the following methods :—

1. A jar may be accurately filled with good water—which can with rare exceptions be got upon the premises, and may with advantage be previously boiled—and then inverted, emptied, and allowed to drain dry in the compartment the air of which is under examination ; a sample then rushes in to fill the place of the original water.

2. The air may be blown in, by bellows which are

FIG. 31.—The flexible bellows-pump employed by Angus Smith to draw out air from the air-jar.

provided with a nozzle longer than is usual, so that it may be placed well down into the jar to within an inch of the bottom ; this insures that the air which originally occupied the jar, will be displaced from below upwards in its entirety.

3. The original air in the jar may be pumped out by means of a small air-pump, and if this is done in the same atmosphere as that of which a sample is desired,

the jar is, of course, refilled by a sample of such flowing in to fill the void.

Angus Smith drew the air out of the bottle by a flexible bellows pump, shown in the accompanying diagram (after Angus Smith).

4. A jar may be accurately filled with mercury, and emptied in the compartment where the sample is to be collected. Although this plan is theoretically a good one, it is practically inapplicable on account of the large amount of mercury required, and from the difficulty of conveying it (from its enormous weight) from place to place.

Each plan, it is seen, involves the encumbrance and expense of special instruments—with the exception of the first; and this is the method recommended on account of the facility of its execution, and from the fact that it is at least on a par with the others as regards its freedom from the possibilities of error.

Whenever it is possible, there is no gainsaying the advantage, in greater exactitude, attained by making the analysis at once in the compartment in which the sample has been taken, since the general atmosphere is that of the jar; and this can generally be done, although frequently at the cost of much trouble and inconvenience. Sometimes, however, the matter becomes practically impossible, and in those cases the extra precision attained—which in careful hands will not be great—need not be aimed at.

Under all the circumstances and conditions in which we are concerned with the collection and analysis of air, it is apparent how necessary it is for the operator to avoid the error which would be introduced by breathing into the apparatus, or into the reagents, &c.

Examination by the Senses.

The extent to which injurious gases are allowed to pollute an atmosphere which is breathed continuously by human beings, is never so great as to afford any evidence of their presence save by the sense of smell.

The sense of smell is doubtless capable of considerable education, and some people possess, naturally, powers in the direction of odour perception, superior by far to those of others; and in the case of these very sensitive ones it may safely be said—with regard to odorous gases—that if such are not appreciable by smell they do not exist in injurious amounts. But unfortunately the sense is remarkably blunt in others, and especially with certain sections of the community whose noses have been constantly subjected to non-refining influences, and which have in consequence grown accustomed to—that is to say, have become blunted in their perception of—bad smells. This consideration alone will suffice to show the advisability of the adoption of further means of detection; but when we consider that many gases are entirely odourless, though not the less harmful on this account, the adoption of such means becomes imperative.

Fortunately the atmospheric impurity which we are by far most generally concerned with, *i.e.*, organic matter from the lungs and skin—gives an index of its presence when it has reached a harmful extent, in a manner which is almost universally appreciated. Everyone is familiar with, and can detect at once, the "stuffy" odour in an atmosphere, as soon as such organic matter accumulates beyond a certain point—everyone, that is, who passes into such an atmosphere direct from the

external air! The atmosphere may, however, be suffered to acquire a high degree of "stuffiness," (with which is synonymous "unhealthiness,") without detection, unless—as is the case with most of our other special senses—we quicken our perception by instituting a comparison,—made in this case between the smell of the external and internal airs.

The perception of odour in the atmosphere is materially influenced by the temperature, the amount of moisture present, and the degree of agitation existing at the time; a low temperature, little moisture, and perfect quiescence, being all unfavourable to odour perception. The more common gaseous or vaporous impurities which furnish an odour are:—"organic matter," empyreumatic and tarry matters, ammonium sulphide, sulphuretted hydrogen, ammonia, coal gas, carbon-bisulphide, &c.; while carbonic acid, carbonic oxide, and marsh gas, are practically inodorous.

Reaction.—The air over open country regions and the sea has no evident reaction to litmus papers, and may be said to be neutral; under those circumstances, however, in which ammonia exceeds its usual amount, a faint alkaline reaction may be sometimes produced.

The air of large towns is slightly acid, owing to the sulphurous acid which is derived from the sulphur compounds contained in the substances used for combustion. A piece of delicate blue litmus paper, moistened with neutral distilled water, denotes this acidity by changing in an hour or two to a faint, though distinct, red.

In the neighbourhood of manufactories, it is evident that the air may be markedly acid or alkaline, according to the nature of the predominant gases which escape in connection with the manufacturing process.

CHAPTER III.

Carbonic Acid.

The estimation of the carbonic acid in the atmosphere is of all air analyses the one of most general importance, and is, on this account, the one most frequently performed. This is not because the carbonic acid is liable to exist in injurious amounts, even under the worst conditions of ventilation commonly obtaining, but because the gas, being a product mostly of respiration, affords an important clue as to the extent to which another and highly injurious product is co-existent, *i.e.*, organic matter from the lungs.

So inert is the carbonic acid itself, that it may exist, when unaccompanied by this poisonous organic agent, to the extent of 1·5 parts per 100. It is therefore *the carbonic acid which has been added to the atmosphere by respiration* which mainly, if not solely, concerns sanitarians, and this simply because it affords an index to the amount of organic matter, which, coming from the same source, increases pretty nearly *pari passu* with it.

The amount of carbonic acid which is present in the general atmosphere,—and which may be termed "normal,"—has been seen to be 0·04 per cent. by volume; it arises mainly from three sources :—

1. The combustion of ordinary fuel, &c.
2. Animal respiration.
3. Organic decay, fermentation, and combustion.

The lowest estimation of carbonic acid made in any atmosphere was 0·02 per cent.

The purest mountain and sea air contains only 0·03 per cent.*

The external atmosphere, during fogs, often contains 0·07 per cent.

Where there is overcrowding it has been estimated as high as 0·7 per cent., and it is commonly under these circumstances 0·3.

Angus Smith found in the worst parts of theatres 0·32 per cent.; in mines, he found an average of 0·785, but in one case the amount reached as high as 2·5 per cent.

Carbonic acid, *per se*, does not appear to be injurious even when it reaches as high as 1·5 per cent., and fatal results would not accrue with less than 5 to 10 per cent.

The relative importance of the estimation of this gas has been recognised for many years, and it is probable that it will ever have an abiding place in hygienic air analysis, although to a degree its use may be restricted as our knowledge of the composition of organic vapours, &c., increases.

We are indebted to Pettenkofer, of Munich, for a method, which, owing to the facility of its performance, is universally adopted; a method which,—though many innovations have been suggested, and sometimes adopted,—has not been materially improved upon since its introduction, now many years ago.

So small is the amount of carbonic acid existing in the atmosphere, under even bad conditions of ventilation (save in mines), that eudiometry fails to indicate its amount, and resort is had in Pettenkofer's process,

* Recent investigations tend to prove the fact that carbonic acid exists in greater quantities in the air over the summits of very high mountains, than lower down towards their base. If this is so, it is difficult to conceive a satisfactory explanation of the circumstance.

to make the gas combine with the lime of lime-water ($CaO + CO_2 = CaCO_3$); and then to estimate the quantity thus absorbed by the diminished alkalinity which the acid has effected in the lime-water.

Pettenkofer's Alkalimetric Method of Estimating the Carbonic Acid in the Atmosphere.

The rationale of the process is as follows:—Clear lime-water*—a strongly alkaline medium—will, owing to the lime it contains, absorb carbonic acid with great readiness, and thereby become turbid ($CaO + CO_2 = CaCO_3$); this carbonic acid is a weak acid, and will diminish on this account the degree of alkalinity (the "causticity") of the original lime-water, according to the extent to which it is absorbed. If, therefore, the degree of alkalinity of a measured quantity of lime-water is estimated, and then this reagent be made to take up all the carbonic acid of a sample of air, the diminished alkalinity of the lime-water—when subsequently tested—will represent the amount of carbonic acid which has combined with the CaO (lime).

More recently other methods have been suggested which appear to have little more than novelty to recommend them, for they have not offered in the writer's hands—as an inducement for adoption—any more true or more readily achieved results. They need not concern us here, save that it may be of interest to point out that they are all based upon two self-evident principles.

(a) That if the turbidity in the lime (or baryta) water taken from the air jar, be matched by adding

* Pettenkofer first used lime-water, and afterwards baryta-water.

known quantities of carbonic acid (in the form of sodium carbonate) to a similar bulk of the original clear lime (or baryta) water, the carbonic acid taken up by the lime-water from the air in the jar can be thus estimated.

(b) If the carbonic acid in the air be absorbed by a strong solution of caustic soda, then the amount of the residual air can be measured volumetrically, and the loss will be due to the carbonic acid removed.

Apparatus required for Pettenkofer's method:—

1. A large air-jar, *i.e.*, a large wide-mouthed glass stoppered bottle of about 4 litres (4000 c.c.) capacity. It is necessary to be acquainted with the exact capacity of the bottle, in order that the amount of air which it will hold may be accurately known. This can be ascertained by filling the bottle quite full of water, and then measuring the water as it is emptied out,—the volume of the water which the bottle holds will likewise be the volume of air which takes its place.

2. A white porcelain dish.

3. A glass stirring rod.

Chemical reagents:—

1. Pure clear lime-water (saturated), made by slaking lime with water and stirring, and then when the lime has subsided pouring off the clear lime-water.

2. A standard solution of oxalic acid (crystallised) made to such a strength (*i.e.*, 2·84 grammes to the litre) that 1 c.c. corresponds in acidity to 0·5 c.c. of carbonic acid.

3. Yellow turmeric paper.

The Process.

1. A sample of the air should be collected in the air-jar.

2. 50 c.c. of perfectly clear lime (or baryta) water are then placed in this, and thoroughly shaken up with the sample of air; the jar is then set aside for from 6 to 10 hours—in order that time may be given for *all* the carbonic acid present in the sample to combine with the lime, and thus create a turbidity of calcium carbonate.

3. 25 c.c. of the clear lime-water are meanwhile tested as to their degree of causticity, (due to the amount of caustic lime present), in the following manner:—the 25 c.c. are placed in a porcelain dish, and the standard solution of oxalic acid is cautiously run in from a graduated burette, until the causticity of the lime-water has been just neutralised by the acid; then the amount of acid necessary to effect this neutrality is read off from the burette. The method of detecting the exact stage when neutrality is reached, is by the use of turmeric paper,—since yellow turmeric paper has the power of turning brown when moistened with an alkaline medium, and this reaction is excessively delicate. A number of small pieces of this paper should be disposed on a clean surface, upon the operator's right; he can then, while adding the acid solution by the left hand, employ the right to mix it up (by a glass rod) with the lime-water, and frequently test the reaction by transferring the wet rod to one of the pieces of turmeric; as the neutral stage becomes near, the degree of browning gets fainter and fainter, and when the stage is exactly reached, the original yellow colour of the paper remains entirely unchanged. Care must be taken not

to add acid beyond this point, or the causticity of the lime-water will be over-estimated—for turmeric has no power of denoting acidity.

4. At the end of from 6 to 10 hours, 25 c.c. of the lime-water are removed from the air-jar, and the causticity is estimated in a precisely similar manner,—but in effecting the removal the precipitate of calcium carbonate which has settled, must be disturbed as little as possible.

5. The difference in the number of cubic centimetres of acid solution required to neutralize (*a*) the original lime-water and (*b*) that which has taken up the carbonic acid of the air in the jar, represents half the amount of carbonic acid in the air—since another 25 c.c. of lime-water remains in the jar, and this has been weakened by carbonic acid to a similar extent to the 25 c.c. which has been removed and tested.

6. The sample of air examined must not be counted as 4000 c.c., for when 50 c.c. of lime-water were added to the jar, an equivalent bulk of air was displaced. The air experimented upon therefore represents 4000 − 50 c.c. = 3950 c.c.

7. The result may be returned as the amount of carbonic acid per cent. (or per 1000 parts) of air, at the "current temperature and pressure," after carefully noting what these respectively were at the time of experiment. Or, as is more usual, it may be reduced to the "standard temperature," *i.e.*, 32° F. or 14·5° C., and the "standard pressure," *i.e.*, 29·922 inches or 760 millimetres of mercury.

To reduce results to the standard temperature of 32° F., it is necessary to bear in mind the fact, that air expands, when heated, to the extent of 0·002 of its bulk for every degree rise above 32° F., and in consequence at this temperature a larger amount of cold condensed

air would occupy the same air-jar, than would be the case with the warmer and more expanded air at 68° F. Supposing that we have found that the carbonic acid represents 0·07 per cent. per volume of the sample of air collected when the current temperature was 68° F., and we require to find what per centage amount by volume this will correspond to at 32° F. It is obvious that we must find how much more of the air than that which constitutes 100 volumes at 68° F. will be contained in a similar number of volumes at 32° F., and that 100 volumes at 32° F. will be found to contain more air than 100 volumes at 68° F. since the 100 volumes at 32° F. will expand in bulk for every degree above that temperature, and thus occupy more space. There is in this case a difference of 36 degrees between 68 and 32, and for each of these degrees the air will contract 0·002 of its volume: that is to say, each volume of air at 68° will become $1 - (36 \times 0{\cdot}002) = 0{\cdot}928$ at 32°, and 100 volumes will become 92·8. Therefore 92·8 volumes at 32° are equivalent to 100 volumes at 68°; or in other words, 100 volumes at 32° will contain the same amount of carbonic acid as 107·2 volumes at 68°. It is necessary, then, to find the amount of carbonic acid in 107·2 volumes at the current temperature, to ascertain the amount which will be present in 100 volumes at 32° F.

But 100 volumes at 68° contain 0·07 of carbonic acid and therefore 107·2 volumes contain:—

$$100 : 107{\cdot}2 :: 0{\cdot}07 : x = 0{\cdot}075.$$

That is to say, since 100 volumes of the air at 32° correspond to 107·2 at 68°, 100 volumes at 32° will contain 0·075 parts of carbonic acid.

The correction to the standard barometric pressure is not necessary unless the experiment is made upon a considerably elevated region; for the circumstances

under which a sample is collected and analysed for public health purposes, the correction need rarely if ever be made, and at best must represent an insignificant figure. The object is to reduce the percentage amounts of carbonic acid at the current pressure, to the percentage amounts at the standard pressure, since air occupies a smaller or larger volume according to the pressure which it is subjected to (*i.e.*, according as the height of the super-imposed column of air is greater or less). The correction is made upon the same lines as that of temperature, when necessary, by the following estimation:—

As the current height of the barometer : the standard height (29·922") : : the percentage amount of carbonic acid at the standard temperature, and at the current height : that of the standard height and temperature.

Suppose for instance the carbonic acid at the barometric reading of 29·5 inches is 0·075, then as:—

$$29{\cdot}5 : 29{\cdot}922 :: 0.075 : x = 0{\cdot}076$$

The amount is seen to be greater, since more air is compressed into the 100 volumes by the greater atmospheric pressure.

Example.—The causticity of 25 c.c. of the original and clear lime-water was tested, by first running in 20 c.c. of the standard acid solution, and subsequently adding this, more cautiously, in cubic centimetres.

30 c.c. of the acid solution were required to just effect neutralisation.

25 c.c. of the lime-water from the air jar required only 27 c.c. of the acid solution to neutralise its diminished causticity.

Therefore $30 - 27 = 3$ c.c. of the acid solution represents the carbonic acid taken up by this lime-water from the sample of air.

But 1 c.c. = 0·5 c.c. of carbonic acid.

∴ 3 c.c. = 1·5 c.c. ,, ,,

The other 25 c.c. of lime-water left in the jar will also have combined with another 1·5 c.c. of carbonic acid.

∴ the carbonic acid combined—or, what is the same thing, the carbonic acid in the air-sample, = 3 c.c. The capacity of the jar was 4000 c.c., and the air examined is 4000 c.c. − 50 c.c. (space occupied by the lime-water) = 3950 c.c.

∴ there are 3 c.c. of carbonic acid in 3950 c.c. of air, or 3950 : 100 : : 3 : x carbonic acid per cent. = 0·0759 — at the current temperature and barometric pressure (*i.e.*, 72° F. and 29·8″).

Notes upon the Process.

There is but little scope for error in the estimation which is a very approximately correct one, and quite near enough for all practical hygienic purposes. Evidently the lime-water does not *remain* of exactly constant alkalinity, even though it is well stoppered, for when 75 c.c. are removed for each experiment, 75 c.c. of the air of the room (containing carbonic acid) are admitted; but while this does not effect results, since it is only necessary to know the causticity of the lime-water at the time of use, it will serve to point out the necessity of making a fresh estimation of this causticity for each experiment. In order that the lime, or baryta water, shall be kept quite pure, and constant in strength, it will be necessary to remove the carbonic acid from the air which enters the store bottle when some of its contents are withdrawn—as by making it pass through the pumice stone moistened with caustic potash. The accompanying figure will

serve to demonstrate how this can be readily effected :— A large glass store bottle is represented fitted with a glass tap to draw off the clear lime-water; any air which enters must pass through the U-shaped tube, which is packed with the pumice moistened with caustic potash.

The turbidity which appears in the clear lime-water on the addition of the oxalic acid solution, is due to the insoluble oxalate of calcium being formed.

If clear and pure baryta water is substituted for the lime-water, it will be found to absorb the carbonic acid much more readily than the latter, and the air sample need only be exposed to its action for an hour. The

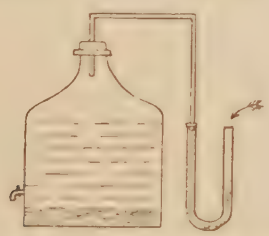


FIG. 32.—Store bottle for lime-water.

strength should be about 7 grammes of the crystallised hydrate to the litre of distilled water.

A simple indicator of the exact stage at which neutrality is reached, is a drop or two of a solution of methyl-orange, which then loses its yellow colour, and assumes a reddish hue.

Conclusions to be drawn from the amount estimated.—It is generally agreed that the air of compartments, which are occupied by human beings, should not show more than 0·06 per cent. of carbonic acid, *i.e.*, the 0·04 per cent. which exists normally in the air, and 0·02 per cent. of "allowable respiratory impurity." This limit is chosen

because, when it is reached solely from respiration, the organic matter, &c., is judged to have reached an unhealthy amount, and is said to be appreciable to the sense of smell (creating a "stuffy" atmosphere). It must be so, however, only to those in whom the sense is extremely delicate, since from the writer's experiments nothing is generally thus appreciated until the carbonic acid reaches 0·08 per cent., in those cases where samples have been collected from rooms occupied under ordinary conditions. The air of inhabited rooms, moreover, is so generally above this limit, without any evidence of harm, and carbonic acid can be furnished to a room from other sources than the lungs of its inmates, that it would appear to be a little arbitrary to demand the limit of 0·06 per cent. in every case.

When the carbonic acid from respiration carries the total up to 0·15 per cent., most of the inmates will then complain of headache, torpitude, lassitude, and faintness; and no further impurity can be detected by the sense of smell after the carbonic acid, from respiration, has carried the total up to 1·3 per cent.

It is, of course, not necessary that rooms in which gas lights are burning shall show only a percentage amount of carbonic acid equivalent to 0·06 per cent., since in these cases there is no concomitant organic matter, such as is given out by the lungs. The extent to which a common gas burner may furnish carbonic acid to the atmosphere is about ten times that of an average adult, *i.e.*, about six cubic feet per hour; and the amount of sulphur compounds thus yielded, in a good gas, is not important hygienically.

The air over burial grounds, especially when these are crowded, contains a high amount of carbonic acid.

Angus Smith devised a rough "**household test,**"

which, though little adopted at the present time, is simple and practical, and as such is of special value for determining as to whether the carbonic acid is above or below "the allowable limit." He found, by experiment, the largest volume of air which could be shaken up with clear lime-water without furnishing a turbidity, so long as the carbonic acid therein did not exceed the allowable amount, viz., 0·06 per cent.. and from the findings of his experiments he propounded the following:—"Let us keep our rooms so that the air gives no precipitate, when a 10½ ounce bottle is shaken up with ½ ounce of clear lime-water;" which is equivalent to stating "let us keep our rooms so that the carbonic acid shall not exceed 0·06 per cent."

CHAPTER IV.

The Organic Matter in the Air.

The organic matter in the air includes that given off from the lungs and skin, and this varies in character and amount in different human beings with the constitution and state of health of the individual. It probably forms pabulum for the nourishment of germs, while at the same time its presence debilitates those exposed to it, and renders them more susceptible to diseases, and less capable of combating them. Its composition is very imperfectly understood, and it probably consists partly of volatile fatty acids and their ethers, and partly of vaporous and suspended matters (epithelial and fatty debris). It is certainly largely nitrogenous and oxidisable, since it will deoxidise solutions of the permanganate of potassium, and will yield ammonia. It quickly putrefies; and when air containing it is aspirated through sulphuric acid, the organic particles are charred and darken the solution. When present in large amounts in water, it can be precipitated by silver nitrate. Probably the major part is molecular and suspended, since it does not diffuse equally about a room, and tends to fall and settle; and there is no doubt that it is mostly in combination with watery vapour, for substances absorb it according to their hygroscopic powers (*i.e.*, it is absorbed chiefly by wool, feathers, &c., and least so by horse-hair). It gives a fœtid smell to the atmosphere, and from the persistence of this it is doubtless burnt off but slowly by the atmo-

spheric oxygen; and in small quantities it gives odour to water. When organic substances decompose in the air they give off gaseous compounds of carbon, nitrogen, sulphur, and phosphorus.

The *processes employed for the estimation of this matter* in air are preferably those with which we have already grown familiar, and which have served to detect the same matter in water. A known quantity of the air —and from choice a large one—is made to slowly pass through doubly distilled ammonia free water,* which will retain all the soluble and suspended material—including organic matter as such, and those gases which afford evidence of the presence or former presence of such matter. The water is then tested for its nitrogenised organic constituents by Wanklyn's method—as to its "free" and "albuminoid" ammonia, and by Tidy's improvement of the Forchammer process—as to its "oxidisable organic matter;" it being borne in mind in the latter test, that either putrescible organic matters, sulphuretted hydrogen, or tarry matters, will, if present, decolourize the permanganate.

The most convenient *method of performance* is to take a glass wash bottle, partially fill with 500 c.c. of doubly distilled ammonia free water, and then tightly fit with a doubly perforated india-rubber cork. Into one perforation a glass tube bent at right angles with one trumpet-shaped extremity is accurately fitted, with the trumpet-shaped end projecting externally (to collect the air), while the other extremity is made to dip well down into the distilled water; the second perforation conducts another bent glass tube, the end contained within the

* The distilled ammonia free water should always be redistilled quite recently, as, even when comparatively fresh, it is often found to contain minute traces of ammonia.

flask being well above the surface of the water, and the other connected directly by india-rubber tubing to the aspirator. The capacity of the aspirator being known (and a convenient size is that of 25 litres), it is filled to the top with tap-water, the tap is then turned so that the water passes slowly out—when air of course enters the trumpet-shaped mouth of the bent glass tube to fill the vacuum created; such air is washed in the distilled water (which has the property of taking up gases, &c., with extreme readiness) before it reaches the aspirator.

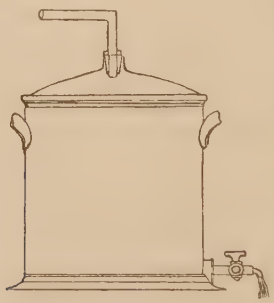


Fig. 33.—An aspirator.

Example.—It is desired to make an estimation of the nitrogenous organic matter;—then, if the aspirator be twice filled and allowed to empty, 50 litres of air will have replaced the 50 litres of water, and these will have been drawn through the 500 c.c. of distilled water; therefore this 500 c.c. of water will contain the nitrogenous organic matter of 50 litres of air.

Suppose the 500 c.c. of water are found to contain by Wanklyn's method 0·05 milligramme of free ammonia, then there will be 0·05 milligramme of free ammonia in

50 litres of air. But in dealing with air the results are expressed in terms of "milligrammes per cubic metre" (*i.e.*, 1000 litres).

Therefore, if there is 0·05 milligramme of free ammonia in 50 litres, there will be 1 milligramme of free ammonia in 1000 litres—or a cubic metre—of air.

Pure air contains *albuminoid ammonia* up to 0·1 milligramme per cubic metre, and averages about 0·08. In a hospital ward this ammonia has been estimated at 1·3.

Generally speaking the external atmosphere (pure air) averages about 0·06 milligramme per cubic metre of *free ammonia*, which has been estimated as high as 0·8 in hospital wards.

The process is made much more troublesome, and is but slightly increased in accuracy, by passing the air through a succession of small wash bottles containing ammonia free distilled water—instead of one large bottle.

In the same manner pure distilled water may be charged with the *oxidisable* organic matter; but before estimating this, any sulphuretted hydrogen, sulphurous and nitrous acids, and chlorine compounds, must be previously got rid of in the manner already seen, and likewise any tarry matter—which will generally give evidence of its presence by yielding a smell or turbidity to the water.

The water may also be tested for oxidised nitrogen (nitrates and nitrites), chlorine, &c. For processes *vide* "Water."

Another, rougher, plan is to surround a thoroughly clean U-shaped glass tube with a freezing mixture of salt and snow (or ice), and to aspirate the air through the tube, when the low temperature condenses the watery vapour in the air as it passes through, and

most of the organic matter is thereby collected. The U-shaped tube can then be washed with ammonia free distilled water, and the washings treated for "free" and "albuminoid" ammonia.

This plan may also be used for the collection and examination of suspended matters.

CHAPTER V.

Ammonia—Marsh Gas—Carbonic Oxide—Sulphur Compounds.

Ammonia.

Traces of this gas are present in every atmosphere—normally, to the extent of about *o·o6* milligramme per cubic metre—and such are derived from organic decomposition (sewage, &c.), from combustion (coal), and from manufacturing processes in which chemicals, &c., containing ammonia are employed. The ammonia exists generally in combination with an acid, so as to form a salt,—such as the carbonate and chloride, and, less commonly, as the nitrate, or sulphate. Ammonia vapours do not appear to injure health, beyond affecting the conjunctiva when in excessive quantities, and it is doubtless one of the most wholesome forms in which nitrogen and hydrogen, as gases, pass into the air. It is in greatest quantity near the ground—over peaty land it is abundant during hot weather—and it is largely present at the back of houses where refuse matter is deposited. Its presence, however, is regarded with scant favour, in spite of its comparative innocuousness, for it is the result of decomposition, and it is a constant ingredient in the most impure airs; it has therefore very bad relations and keeps very bad company.

The gas may be detected by moistening strips of filtering paper with Nessler's reagent, and hanging

these up for some time in the air of the compartment; or if a sample of air is collected in a jar—by catching one of these prepared papers between the stopper and the neck, in such a way that it hangs down into the jar free of the sides for a few minutes. Or known quantities of air may be aspirated through doubly distilled water, and the ammonia estimated quantitatively by "Nesslerisation."

Marsh Gas (CH_4).

This gas probably exists in traces in most atmospheres, although owing to the difficulties of its detection it is not easy to speak definitely upon this point.* There are certainly traces in the atmosphere of towns, and over districts of abundant vegetation (especially when such districts are marshy) it exists in large quantities. As it is evolved from strata in which mining operations are progressing, it is known as "fire-damp;" and its character of exploding, when ignited in the presence of carbonic acid, is often disastrously exemplified.

There is no doubt that marsh gas, though apparently extremely innocuous, may create, after a while, symptoms of chronic cachexia (poisoning); and being inodorous and non-irritating, its presence would not be detected by the senses. Any escape of coal gas, containing as it does 35 per cent. of marsh gas, will charge the atmosphere with considerable and dangerous amounts of this substance, but fortunately in these cases the strongly smelling ingredients of the coal gas give timely warning.

* A. Muntz and E. Aubin found that a million volumes of such air, previously freed from all dust and CO_2, yielded, when passed over red-hot cupric oxide, from 3 to 10 volumes of CO_2.

Carbonic Oxide (CO).

Owing to the properties which this gas possesses of entering into combination with the hæmoglobin of the red corpuscles, displacing their oxygen, and thus paralysing their oxygen-carrying functions, it plays the part of a virulent narcotic poison; and since it gives no indication of its presence to the senses, its powers for evil are materially enhanced. It becomes, then, an urgent duty to examine the air for this gas in those cases where there is any likelihood of its presence, and this will always be the case in the atmosphere of compartments where iron or copper stoves are employed, and especially so when the material is cast iron, and when the fuel is coke; where coal gas (which contains 6 per cent.) is incompletely burnt or escapes; or where there is a possibility of some of the products of combustion from furnaces, flues, &c., escaping into a compartment—for the air in furnace-flues has been found to contain over 20 per cent. of carbonic oxide, and that of ordinary flues from domestic fire-places as much as 4 per cent. The carbonic oxide of the air of flues is always the product of incomplete combustion, that is to say, the carbon of the organic material burnt is either not fully oxidised to carbonic acid (CO_2), owing to the supply of fresh air being insufficient, or else the carbonic acid, being formed low down in the furnace, gets reduced in passing through the rest of the furnace to carbonic oxide.

It will also be of service to remember, that of the gases generated from the explosion of gunpowder, carbonic oxide forms nearly 8 per cent. (7·5 per cent.); and that a serious drawback to the adoption of "water gas"

as a source of heat and light, is the fact that it contains (before combustion) 25 to 40 per cent. of this very dangerous ingredient.

The carbonic oxide in the atmosphere of stove-heated rooms, is derived from either of the following sources (and probably to some extent from all) :—

(1) Red-hot cast iron will transmit the gas from the fire—either through its substance, or through minute fissures; and the hot iron will even itself reduce CO_2 to CO.

(2) The carbon which enters into the formation of the cast iron, may get oxidised and reach the external atmosphere.

(3) Particles of suspended organic matter in the atmosphere get charred and partially oxidised, by coming in contact with the heated stove.

(4) Currents passing down the smoke flue, as they do under certain conditions, may thus introduce the gas.

Qualitative Test of its Presence.

The best is Vogel's,—but a knowledge of the spectroscope is necessary to the test, and for those unacquainted with the use of this instrument a short introductory description is appended :—

If a compound light, such as sunlight, is made to pass through a glass prism, the different coloured rays of which it consists are unequally refracted, (or bent out of their original course), so that beyond the prism they form, upon a white surface, a continuous line of colours called the "spectrum;" and the spectrum of the compound white light will be seen to consist, in order, of red, orange, yellow, green, blue, indigo, and violet.

A number of dark lines—called absorption bands, or Fraunhofer's lines—are also seen to cross the image of the solar spectrum.

In other lights, however, the spectrum will only show a very few *bright* bands (that of the sodium flame only *one*), and the remainder of the spectral image is thus rendered almost—or quite—invisible, by comparison.

If now we transmit solar light through different coloured solutions, we then get different absorption bands—though analogous to the lines of Fraunhofer.

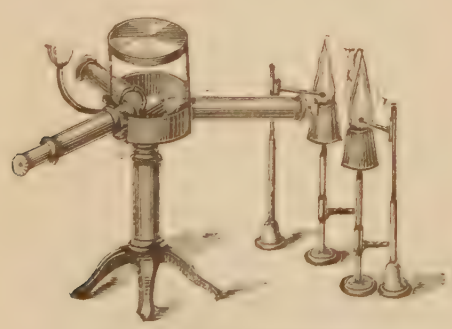


FIG. 34.—The spectroscope.

If a solution of fresh blood, for instance, be taken, and the cell containing it is placed before the slit in the instrument which admits the light, two distinct and characteristic absorption bands are seen.

The accompanying figure will serve to show the manner in which the spectroscope is constructed:—

A firm iron stand is seen to support, at its upper end, a brass plate carrying the glass prism; laterally a cylinder is also fastened to the brass plate, and in the end of this cylinder which is nearest the prism is placed a lens, the other end being closed by a plate

with a vertical slit in it (the breadth of which can be regulated by a screw to meet requirements), and through which slit the light (represented by two coloured flames in the figure) is admitted to the prism—the rays being first rendered parallel, and condensed, by passing through the lens. The spectroscopic appearance is then viewed through a small telescope (with a magnifying power of 8), and this is fitted on to the cast iron foot, so as to be moveable in a horizontal plane about the axis of the foot. The other tube seen in the figure contains a fixed scale, which is reflected from the front surface of the prism into the telescope, and serves the purpose of fixing the width and distance apart of the various characteristic lines—it is illuminated by a small gas flame, as shown in the figure.

All foreign light must of course be cut off, and this is done by a black cloth having a circular opening to admit the illuminated tube just referred to, and which is thrown over the prism and the other tubes.

By a spectroscopic examination, therefore, the colour, number, and position of the bright lines on the spectral scale, are carefully observed and noted.

The most convenient and delicate method of performing spectroscopic observations is by means of the Sorby-Browning micro-spectroscope, which simply consists of a small spectroscope placed in connection with a microscope, in such a way that the former fits into the tube of the latter in the same manner as an eye-piece.

Vögel's test is so delicate that it more than suffices for all practical purposes, detecting as it does as little as 0·03 per cent. To the sample of air collected in the jar, a little pure water is emptied; and the finger is then pricked so that a drop of blood may be made to fall also into the jar. The whole is then vigorously shaken up

and allowed to stand for a short while, when a little of the reddish liquid is removed and examined by the spectroscope, and the appearance on the scale is carefully noted. The spectral appearance will be that of **oxy-hæmoglobin.**

Oxidised hæmoglobin shows two well marked bands in the yellow and in the green parts of the solar spectrum, both lying between Fraunhofer's lines D and E. The spectral appearance of hæmoglobin in the presence **of carbonic oxide is almost identical.**

A few drops of a solution of ammonium sulphide are next added, the bottle is well shaken, and the liquid is re-examined. If no change whatever in the spectroscopic appearance of the fluid has ensued, carbonic oxide *is present*; otherwise the ammonium sulphide having de-oxidised or reduced the hæmoglobin, the two bands will be represented by a single band, shaded off

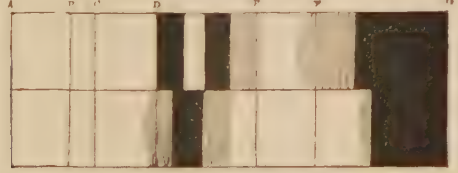


FIG. 35.—Showing the characteristic disposition of the absorption bands, in the spectroscopic picture of oxy- and reduced hæmoglobin. The upper scale representing oxyhæmoglobin and the lower reduced hæmoglobin.

at the borders, and occupying a position intermediate with regard to the original two bands.

A Quantitative Test.

The subchloride of copper has the peculiar property of absorbing this gas; and advantage is taken of the fact to estimate the quantity present by the method of eudiometry.

It will be unnecessary to repeat here what has already been described in connection with oxygen and nitrogen; it will suffice to state that a volume of air is measured in the Hempel's burette (at the current temperature and pressure), and then passed over, slowly and repeatedly, into the absorption pipette charged with the solution of subchloride of copper. Time must be allowed for complete absorption, which takes place slowly; and two or three readings should be repeated until a "constant reading" is obtained, to ensure that all the gas has been absorbed. The loss in the original volume, taken under the same conditions of temperature and pressure, is due to carbonic oxide present, and represents its amount.

Notes upon the Process.

It is necessary to use an absorption apparatus with large bulbs, in order that a good quantity of the copper solution may be employed; and this is especially desirable because the oxygen in the air somewhat impairs the powers of the copper solution. Having in view this fact, it is desirable to first remove the oxygen, and then examine the residual gases for carbonic oxide—in those cases where a very correct estimation is required. The faintest traces will escape detection (as in the case of carbonic acid) by this method of endiometry, and there-

fore its utility for hygienic purposes is not great when one considers the fact that an amount of under one per cent. has caused narcotic poisoning, and that traces far short of this must of necessity, from the nature of the gas, work insidious harm to animal life. It seems, therefore, that the qualitative test of Vogel's, which will detect slighter traces, will suffice for sanitary purposes—since it is not necessary to estimate the *amount*, when the faintest trace suffices to make an atmosphere very undesirable. The solution of the subchloride of copper is made by exposing copper-turnings and the oxide of copper to the action of strong hydrochloric acid.

Sulphurous acid, sulphuretted hydrogen and ammonium sulphide may all be present in the atmosphere of large towns, the first two invariably so, in traces; the latter is, however, less often appreciable. They are also added to certain atmospheres by combustion and trade processes.

There is no doubt but that their presence is deleterious to health, and creates in time a chronic unhealthy (cachectic) condition.

The external atmosphere chiefly gains sulphurous acid from the combustion of the coal used in manufactories, especially when this is impure and contains quantities of pyrites. The gas is distinctly injurious to vegetation, and it is an open question whether—diluted as it is in the atmosphere—it can even have the disinfectant powers which have been ascribed to it by some.

Angus Smith considers sulphuretted hydrogen "one of the most deadly of gases," and holds that "it lowers the tone of health, and may gradually diminish vitality to such an extent, that disease ensues." Chemists are, however, exposed to it daily with no marked ill-effects!

Sulphurous acid, in large quantities, appears to favour the development of—even if it does not induce—chronic chest conditions, anæmia, and conjunctivitis, &c. A cubic metre of air examined at Lille, was found to contain on an average 1·8 cubic centimetres.

These gaseous compounds of sulphur may all be detected by exposing to the air strips of filtering paper moistened with a solution of lead acetate. Any faint evidence of darkening about the borders of the previously white paper will prove their presence in the atmosphere. The darkening may be due to ammonium sulphide; but if this is present, the air will at the same time be alkaline in reaction, and similar paper moistened with the blue solution of the nitro-prusside of sodium will turn violet.

A quantitative examination may be made by drawing a known volume of air through distilled water by means of an aspirator, and having created a colour in this by adding lead acetate solution, match the colour in a similar bulk of pure water (which is treated with a like amount of lead acetate solution) by adding known quantities of the sulphur compound. In the case of ammonium sulphide, the violet colour produced by the nitro-prusside of sodium may also be similarly titrated.

Hydrochloric, nitric and nitrous acids provoke chronic chest conditions; and **carbon bisulphide** induces serious chronic nervous derangements. Their presence is indicated by tests given upon a subsequent page, or large volumes of the air may be passed through distilled water — which may be afterwards tested for these gases.

CHAPTER VI.

Ozone (O_3)—Aqueous Vapour.

This gas is an allotropic oxygen, in which the molecule is represented by 3 volumes of oxygen instead of 2. It is a gas with a peculiar phosphorous odour, and possessing marked irritating properties upon the mucous membrane of the eyes and nose, and upon the respiratory tract; the function it performs in nature is to oxidise oxidisable products, and thus to purify the atmosphere. It is best prepared artificially by passing electrical discharges through moist air, and hence it will be readily understood that its chief natural source is atmospheric electricity, and that it exists in greatest quantities during and after thunderstorms—when it is also generally associated with nitric and nitrous acids and peroxide of hydrogen. The peroxide of hydrogen is also a powerful oxidising agent, by parting with some of its oxygen and becoming water ($2H_2O_2 = 2H_2O + O_2$); and nitrous acid will also part with its oxygen with great readiness.

According to the late Dr. Tidy:—

1. Most ozone is found after thunderstorms, and least in damp and foggy conditions of the atmosphere.

2. More is found on the coast than inland, especially when sea breezes are blowing.

3. More is found at high than at low levels.

4. More is found in country than in town districts, and M. Houzeau suggests that this fact may be due to the freer movement of air.

5. More is found in winter than in summer.

6. More is found during the night than the day, and the greatest quantity at dawn.

7. Western winds in Great Britain contain more than Eastern. M. Houzeau points out that the manifestation of ozone is affected chiefly by the *intensity* of the winds in most cases, except where these blow directly off the ocean.

8. It is rarely, if ever, found in the air of dwelling rooms when occupied.

Test.—The *common test* for ozone is that of exposing to the atmosphere a white porous paper (filtering or blotting), after this has been soaked in a solution of potassium iodide and starch and then dried. Ozone will free the iodine, which then combines with the starch to form the blue iodide, and thus a blue colour is created ($O_3+2KI+H_2O=2KHO+I_2+O_2$). The papers are exposed for a definite time in a cage, which aids in protecting them from direct sunlight, dust and rain—all of which must be excluded (together with wind), or subsequent bleaching and fading of the colour ensues.

The test is a coarse one, however, and fallacy arises from the following causes:—

1. The oxides of nitrogen, peroxide of hydrogen, and chlorine (which may also be formed by electrical discharges in the atmosphere) will produce the same results upon the papers.

2. The freed iodine is partially volatilized, and thus its effect is lost; while some of it may return to the potash and form inert iodide and iodate.

3. It is impossible to get uniform atmospheric conditions, *i.e.*, the amount of light, moisture, temperature, and wind—vary, and make results inconstant; and the purity and strength of the starch varies considerably.

The greater the movement of the air (wind), the greater the quantity of ozone which is brought to act upon the paper, and hence less quantities of this gas present on windy days may create more bluing than greater quantities on still days.

A better test (Houzeau) is the bluing of faintly reddened litmus paper when moistened with a solution of potassium iodide and dried—when the potash formed by the ozone, being alkaline, gives the paper a blue tint. Ammonia is the only other gas in the atmosphere which can produce the same effect, and consequently another piece of the litmus paper, *not* treated with potassium iodide, is exposed at the same time. Then if the whole colour is not due to ozone, any difference in the shades of the two papers *must* be created by this gas—which can thus be estimated.

The principles upon which a quantitative estimation of ozone (*i.e.*, "ozonometry") is made, are colorimetric. The intensity of the blue colour created by the ozone acting upon the papers when these are exposed to the atmosphere, is matched with one of a series of papers forming a standard scale (1 to 10) of tints—each tint having been produced by exposing such papers to *known* amounts of ozone; the same tint of blue will, of course, in either instance, be produced by similar quantities of the gas.

Aqueous vapour must only be briefly considered here.

It is best estimated by hygrometers, *i.e.*, instruments which read the amount of moisture present in the atmosphere. The best of these is probably the combination of wet and dry bulb thermometers, the readings of which, when applied to Glaisher's Tables,* form a ready means of making the calculation.

* *Vide* pages 240, 241.

The wet and dry bulb hygrometer consists of two thermometers, identical in every respect, and fitted on to a stand. The bulb of one of the thermometers (the "wet thermometer") is covered with thin muslin, and around its neck are twisted conducting threads of cotton which pass thence into a small vessel of pure water,—placed at such a distance as to allow a length of about 3 inches of thread: this vessel is fixed upon one side, so that the evaporation of its contained water may not affect the readings of the dry bulb thermometer. The cotton is previously freed from fat by ether, and then it conducts the water from the vessel to the muslin surrounding the bulb of the thermometer, where it evaporates quickly or slowly according to the dryness ("drying power") of the atmosphere; and as during evaporation there is a reduction of heat, the temperature recorded by the wet bulb is always reduced below that of the dry bulb—except of course in those cases where the atmosphere is already saturated, and no evaporation on this account ensues. The temperature of the air, and of evaporation, is thus given by the difference in the readings of the two thermometers; from which can be ascertained by means of Glaisher's Tables the various hygrometric data.

The instrument should be placed in the shade, with the bulbs of the two thermometers well exposed—though protected from any radiant heat which may pass from the walls of occupied houses. The observations are generally taken at a height of 4 feet from the ground.

The amount of watery vapour in the atmosphere varies much from time to time, and from place to place, and is greatly dependent upon temperature; warm air having the power of holding more invisible moisture than cold. It may range from 30 per cent. of the

amount necessary to create complete saturation, to complete saturation itself, taken as 100. From 65-70 per cent. of saturation is probably the degree most conducive to general good health, and 75 per cent. is very agreeable—a difference between the dry and wet bulb thermometers of about 5 degrees, that is!

Abnormal dryness of the atmosphere gives rise to an oppressive feeling, and obtains chiefly in store heated rooms, or in rooms ventilated with hot air; and abnormal dampness, gives rise to numerous conditions familiar to everyone.

All air contains *some* moisture, and when the temperature is lowered to a less or greater degree, at last—according to the amount of this invisible moisture present—a degree is reached at which the air is no longer capable of holding the vapour, and it is deposited in a solid visible form; the temperature to which it is necessary to reduce the air of any place in order that it shall thus deposit its moisture, is called "the dew-point."

The amount of vapour which will saturate a cubic foot of air under the standard barometrical pressure at

32° F. = about 2 grains.*
35° F. = ,, 2½ ,,
40° F. = ,, 3 ,,
45° F. = ,, 3½ ,,
50° F. = ,, 4 ,,
55° F. = ,, 5 ,,
60° F. = ,, 6 ,,
65° F. = ,, 7 ,,
70° F. = ,, 8 ,,
75° F. = ,, 9½ ,,

* For precise amounts see Table on page 241.

CHAPTER VII.

Suspended Matter in the Air.

The nature of the suspended matter in the atmosphere must, of course, vary widely with the place and the circumstances of its collection; and it would not be going too far to say that particles of almost everything the observer can see about him may be present to a greater or less degree. Under these circumstances, the task of tabulating here these various materials would become a difficult and tedious one; but those which are of more common occurrence will be given.

Although under general conditions they are invisible to the unaided eye, everyone must have been struck with the enormous quantities of these suspended matters when a ray of sunshine enters a room, and the rays of light reflected from their tiny surfaces disclose their presence. Obviously their number increases according as the atmosphere departs from its state of greatest purity; high mountain air on the one hand containing few, and low town air containing many (soot, dust, &c.).

These minute solid particles, which mostly have a tendency to settle when the air is still, gain access to the atmosphere chiefly in the following manners:—

They are lifted up by air currents; by the bursting of the bubbles which may form upon the surface of liquids; by the ascensional force of evaporation; by combustion; and by volcanic upheavals.

It is more especially in the work-rooms of factories that this examination of suspended matters becomes an urgent desideratum, since both the nature and amount of these have been abundantly proved to be concerned in the production of disease.

The collection, and microscopical examination, of the dust which settles in a room, gives a rough means of investigating the subject—but it is necessary to deal with methods which are more inclusive and precise.

The methods of collection.—

Undoubtedly the *best method* is to aspirate large volumes of the air slowly through small amounts (say 100 c.c.) of distilled water, placed in 2 or 3 small wash bottles. These are then covered up and set aside—so that the suspended matter may settle as much as possible—when the supernatant fluid is siphoned off, or decanted; specimens of what remains behind in the bottles are next removed by a pipette, and mounted for examination. At the same time some of the apparently clear supernatant liquid should be examined for those suspended matters which have not settled. The method can be made quantitative by aspirating measured quantities of air through water and counting the number of particles in an aliquot part of such water.

Another plan is by means of *Pouchet's aëroscope*.

This instrument consists of a vertical glass cylinder, capable of being hermetically closed at either end by a copper ferule. The ferule at the upper extremity of the cylinder is a permanent fixture, and gives passage to a vertical copper tube which is partly outside and partly enclosed within the cylinder; of this tube, the extremity of the part which is outside the cylinder is expanded into a trumpet-shaped mouth (so as to better collect the air) and the end of the part which is inside the cylinder

is gradually drawn to a very fine point, not more than 0·5 mm. in diameter.

The ferule at the lower extremity can be removed, so that a circular glass plate—which has been previously smeared with glycerine—can be placed immediately under the finely drawn point of the copper tube. The whole apparatus is then made air-tight, and connected with the aspirator. The air which is thus sucked in falls in a spray upon the glass slide, and the glycerine retains the suspended matter.

A modification of Pouchet's aëroscope is the instrument of M. Marié-Davy, a description of which is not

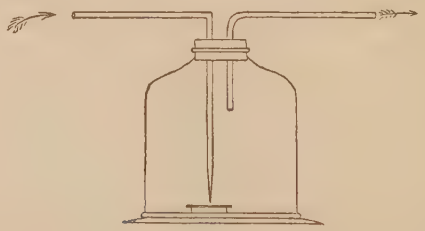


FIG. 36.—M. Marié-Davy's modification of Pouchet's aëroscope.

necessary, since from what has been written the accompanying figure sufficiently explains itself.

Hesse's apparatus is seen by figure 37 to consist of a long glass tube connected at one end to the aspirator; the small india rubber cap which closes the other end is removed just before use, and 50 c.c. of pure glycerine is poured into the tube, which is then turned round on its horizontal axis so as to make the glycerine coat the whole interior. As the air is subsequently aspirated through the tube, the suspended matter is caught up by the glycerine—which can be removed and examined microscopically.

Methods in which glycerine is employed are somewhat unsatisfactory, since it is rare that the original "pure" glycerine will not contain marked evidence of solid particles. A preliminary microscopic examination of the glycerine would not, however, entail much additional labour or loss of time!

A *third plan* entails the use of a pure sugar filter through which the air is slowly drawn; the sugar is then dissolved in a sufficiency of pure water, and the sus-

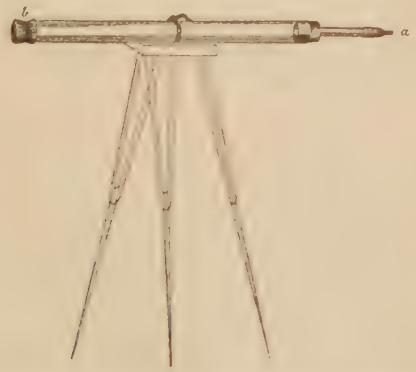


FIG. 37.—Hesse's apparatus for the collection of suspended matters in the air. *a*. The extremity connected with the aspirator. *b*. A removeable cap.

pended matters caught up in it are retained in suspension in the water, when they may be collected and examined microscopically.

The filter is best arranged as a glass tube, at least an inch in diameter, disposed horizontally, and packed—not too tightly—for several inches with the sugar crystals. One end of the tube is left open for the entrance of air, and the other connected by india-rubber tubing with an aspirator. The filter dissolved—the suspended

matter may be separated by filtration through a weighed Swedish filter-paper, then dried at a low temperature and weighed. If the amount of air aspirated has been recorded, the weighed quantity of its original suspended matter may be expressed as milligrammes per cubic metre, *i.e.*, a quantitative estimation may be made.

Objections may be raised to each of these processes, but such are not of great import: it may be argued for instance—and truly so—that some substances will pass through the water in the aspiration method, or may be deposited in the tubes and bottles. These considerations, however, will only affect conclusions when extremely refined work is desired.

The Nature of the Suspended Matter.

This is, of course, either animal or vegetable (dead or living), or mineral. The more common substances found are:—

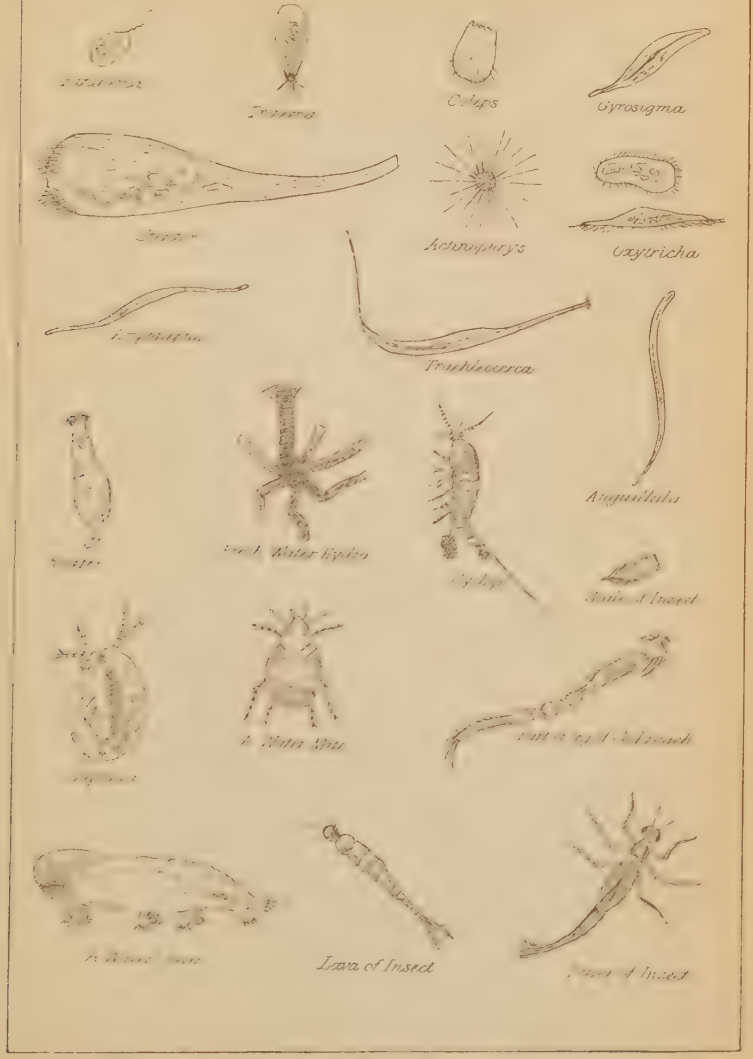
Animal.—

1. *Dead.*—Debris from wear and tear of clothes, &c.; wool, silk, &c., fibres; human hair; particles of feather; molecular debris (?) in considerable quantity; debris of dried epithelial cells, and epidermic scales from skin; pus cells; pyogenic micro-organisms; fragments of insects, *i.e.*, scales from wings, legs, and particles of the spider's web; dried fæcal particles from horses' dejecta, &c.

2. *Living.*—Minute ova; infusorians—minute forms even grow in the atmosphere—chiefly amœbiform.

Vegetable.—

1. *Dead.*—Soot or particles of carbon, &c.; molecular debris (?) in large quantity; vegetable fibres, hairs, and


Cleps
Gyrosigma
Achnanthes
Oxytricha
Trachelocerca
Acinetula
Larva of Insect

cells, &c.; cotton, &c., fibres; starch grains; portions of plants, and pieces of woody fibre; pulverised straw; dead spores, &c., of moulds, fungi, diatoms and bacteria.

2. *Living.*—Pollen seeds; spores of fungi, moulds, and diatoms (which may even live and grow in the atmosphere), and rarely mycelium of fungus*; algæ, notably protococcus pluvialis, and also the small oval cells of other unicellular algæ; bacteria and their spores.

Mineral.—Especially numerous when the ground is dry. Minute particles of every chemical constituent of the soil may be raised up into the atmosphere, *e.g.*, silica, silicate of aluminium, sand, mud, salts of sodium potassium and calcium (carbonate and phosphate), peroxide of iron, &c.

Sodium chloride is invariably present, and in greatest quantities at the sea-side.

Lead, arsenic and zinc from the wall-papers, paint, and "dryers" employed upon the walls of rooms; and arsenic also from artificial fruit, flowers, curtains, &c., used for ornamentation. Molecular debris (?), coal ashes, &c.

There are certain trade-dusts which vitiate the air of the immediate neighbourhood in which the trade processes are carried on; and particles of the following substances find their way into the atmosphere:—

Coal and tin, in coal and tin mines; and the former also exists to a considerable extent in furnace and engine rooms.

Stone, in quarries, and places where the stones are ground, &c.

Slate, in quarries, and places where they are prepared.

* The spores and mycelium of Achorion Schönleinii and Tricophyton tonsurans have been found in the atmosphere of skin wards.

Cement, in cement works, &c.

Sand, where collected and employed.

Wood, as sawdust in saw-mills, carpenter's shops, &c.

Soot, when chimneys are swept, &c.

Earthenware, clay, and china—in the work-rooms.

Steel, where such is ground and worked up—as by cutlers, file-makers, steel-grinders, needle and pin makers, tool makers, &c.

Lead, where such is being worked with—as by file-makers, printers, white-lead manufacturers, plumbers, painters, glaziers, lapidaries, file-makers, lead-miners, type-founders, glazed card manufacturers, earthenware manufacturers, &c.

Fabrics of clothing, *i.e.*, wool, silk, cotton, linen, flax, &c., in factories of these articles.

Wheat, and other flour, in mills, bakeries.

Arsenic, in wall-paper, and artificial flower manufactories.

Copper, in brass founderies, copper smitheries, and tin-plate works.

Bichromate of potassium, &c., in manufactories of such.

Pearl-dust, in button, &c., manufactories.

Glass, in glass-works, sand-paper making, &c.

Phosphorus in match manufactories, especially before the red or amorphous phophorus was used.

Mercury, in silvering and gilding works — before electrolysis was employed.

PLATE III.

ommonly found in impure water (and air).

CHAPTER VIII.

The Characters of the Air Collected from Various Sources.

Marsh Air.

The air collected over marshy regions is contaminated by the products of vegetable putrefaction and fermentation; for the circumstances of moisture are just those which favour these changes, *i.e.*, sufficiency, but not excess; and the temperature being favourable will also aid materially in these changes.

Such air contains:—Excess of carbonic acid—about 0·055 per cent. being the mean; marsh gas in considerable quantity; sulphuretted hydrogen is also sometimes in considerable quantity; watery vapour in large amount; ammonia in traces; ozone in faint traces generally; phosphuretted hydrogen in faint traces. Decaying organic matters, (vaporous and solid), together with living minute forms of animal and vegetable life, constitute almost entirely the suspended matter; such is found, therefore, to mainly consist of vegetable debris, algæ, diatoms, fungi, bacteria and other micro-organisms, (which in some countries may include the bacillus malariæ)—most of which gain access to the atmosphere by the ascensional force of evaporation.

In those cases where the presence of sulphuretted hydrogen is marked, there must be soluble sulphates in the marsh water which have become deoxidised to sulphides by reducing agents (chiefly organic matter)—from which the sulphuretted hydrogen is doubtless formed by the action of vegetable ("peaty," &c.) acids.

Sewer Air.

Sewer air is of course variable in composition. Its reaction is generally alkaline.

Oxygen is variously diminished, according to the efficiency of the sewer ventilation; it is sometimes in normal proportions.

Carbonic acid is variously increased from the same cause; it probably does not average more than twice the normal amount.

Ammonium
Sulphuretted hydrogen } are present in small quantities.
Ammonium sulphide
Carbon bisulphide

Marsh gas is small in amount, or absent.

The fœtid and putrid organic vapours of sewage, are, according to Odling, allied to the compound ammonias, and are probably carbo-ammoniacal, and contain traces of ptomaïnes and leucomaïnes (*i.e.*, animal alkaloids).

Moulds, fungi, and bacteria (chiefly bacilli), and their spores, together with animal and vegetable debris, appear to constitute almost the entire suspended matter. Micro-organisms average about 6 per litre in the air of a good sewage system.

Air over Burial Grounds.

The oxygen is slightly diminished.

The carbonic acid varies, but is commonly about twice the normal amount.

Ammonia
Ammonium sulphide } in faint traces.
Sulphuretted hydrogen

Organic vapours.

Animal and vegetable debris, fungi, bacteria, &c.

The Air of Mines.

The oxygen is diminished in proportion to the efficiency of ventilation; the carbonic acid is increased also proportionate to the ventilation; marsh gas, in small or large amount; frequently a little sulphuretted hydrogen is present; organic matter—chiefly vegetable; few moulds, fungi, or bacteria.

Blasting by gun-powder yields to the atmosphere:—carbonic acid, carbonic oxide, carbon, hydrogen, sulphuretted hydrogen, and mineral salts (of potassium).

The Air during Fogs.

Reaction acid; the oxygen is diminished; the carbonic acid very much increased--may reach 0·09 per cent.; sulphurous acid in small quantity; carbon bisulphide in traces; carbonic oxide in traces; ammonium sulphide or carbonate in small quantity; sulphuretted hydrogen generally in faint traces; watery vapour excessive; fine suspended particles of carbon and tarry matters, together with the commoner forms of suspended matter in air (*quod vide*).

Ground Air.

Ground air may be sucked from considerable distances into a house, owing to the aspirating effect of the warmed and expanded air of the house itself; and the foul air of cesspools has been shown to be sucked through the earth into a dwelling, for distances of over 20 feet.

When it is borne in mind that many houses contain cellars built in and ventilated considerably below the ground level, it is not difficult to see how "ground air" must enter materially into the constitution of the atmosphere of such cellars.

A consideration of the character of ground air will show its undesirability! It contains an enormously high percentage of carbonic acid, and the maximum amount

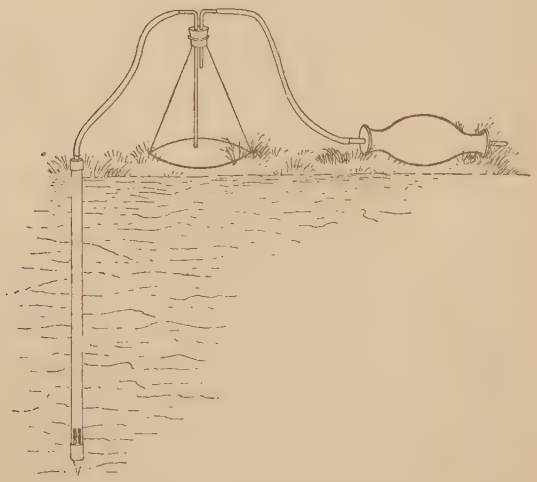


FIG. 38.--Hesse's apparatus for collecting ground air.

of this impurity is always found between July and November—doubtless due to the amount of vegetable life which dies off in the early autumn, and the circumstance that at that season the temperature and moisture prevalent favour its rapid decomposition.

The escape of large quantities of ground air into basements and cellars will, then, be best detected by examining the atmosphere for carbonic acid, and any

considerable excess of this gas not otherwise accounted for, points to such pollution; other impurities likewise being present it becomes a question as to whether these are derived from the same source, and the matter can be settled by collecting a sample of the ground air in the vicinity of the house, analysing it, and comparing it with that of the house basement.

A sample of ground air is conveniently taken in the following way:—A sharp-pointed narrow steel cylinder, with numerous perforations just above its point, is driven into the earth to depths varying from 1 to 6 feet. The upper end of the tube is connected with a large air jar, which is again connected to an aspirator. The connection between the jar and the steel cylinder is shut off, and the jar is first emptied, by means of the aspirator, of the air it contains; the connection is then re-established and the sample collected.

CHAPTER IX.

Scheme for the Detection of Gases when present in large Quantities.

(*Mainly constructed for use of Candidates for Examinations in Hygiene*).

Whereas for the detection of the various gases which contaminate an atmosphere, no better course can be pursued than that of passing air through doubly distilled ammonia-free water, and then treating this water according to the tests already given—yet, when these gases exist in considerable quantities (as in the atmosphere of chemical manufactories, or those manufactories in which chemicals are employed), they can be discovered by tests applied directly to the air itself—such as by the exposure of strips of filtering paper appropriately prepared, &c.

To test the knowledge of candidates presenting themselves for examination in Public Health, generally a large amount of a gas is put into a small air-jar; and two or three of these jars, containing each a different gas, are placed before the candidate. In these cases he cannot do better than adopt the following ready method of procedure, which has been devised to meet these special circumstances, and is of course of no use where small quantities of gases are concerned.

1. The air-jar contains large quantities of the gas.

2. Partially remove the stopper, smell, and replace as quickly as possible.

Free chlorine has a peculiar and disagreeable odour, and is particularly irritating to the throat and lungs; when in very small quantities the odour closely resembles that of seaweed.

Hydrochloric acid has a fainter chlorine-like odour.

Carbonic, nitric, and nitrous acids, have no marked smell.

Sulphurous acid has a pungent sulphur-like smell.

Ammonia, ammonium sulphide, and sulphuretted hydrogen, all possess well-known and characteristic smells.

Carbon bisulphide has a peculiar and disagreeable garliky odour.

3. Moisten two pieces of delicate red and blue litmus papers in neutral distilled water, and catch these between the stopper and the neck of the bottle—in such a way that they hang down into the bottle free of the sides. Note any change in the colour of these papers after waiting a minute or so.

4. Pour rapidly into the jar a small quantity of distilled ammonia-free water (*i.e.*, about the amount which half fills a small test-tube), and replace the stopper at once; then shake vigorously several times, so that the bulk of the gases may be taken up.

5. Half of this water is then decanted into a test-tube and tested as follows:—

A. *If the blue litmus paper turns red* (*i.e.*, the gas is acid), it is either carbonic acid, hydrochloric acid, sulphurous acid, nitric or nitrous acids.

Add a drop or two of a solution of silver nitrate to some of the distilled water emptied from the jar into a test-tube.

(*a*) *There is a white precipitate*, which denotes the presence of either:—

1. *Carbonic acid.*—*Very* slight precipitate, which is in-

soluble in nitric acid; acidity also *very* faint; clear baryta water added to the jar becomes turbid—which turbidity is increased by adding liquor ammoniæ.

2. *Hydrochloric acid.*—*Marked* precipitate; insoluble in nitric acid, but soluble in liquor ammoniæ; acidity also *marked*.

3. *Sulphurous acid.*—*Marked* precipitate; soluble in nitric acid; the original precipitate on being heated darkens (Ag_2S).

(*b*) *There is no precipitate*, from which is inferred the presence of either :—

1. *Nitric acid.*—Add brucine and sulphuric acid to the original water, and note the appearances of the pink zone changing to yellow and brown; or add a crystal of ferrous sulphate and then sulphuric acid to the original water, and note the brown coating of the green crystal.

2. *Nitrous acid.*—Add a drop each of the solutions of starch and potassium iodide, and then a drop of sulphuric acid—a blue colour forms in the presence of this acid; or the meta-phenylene-diamine test may be applied.

B. *If the red paper is turned blue* (*i.e.*, the gas is alkaline), it is either :—

1. *Ammonia.*—Add a drop or two of Nessler's reagent to some of the distilled water from the jar, and a yellow to amber colour appears; odour characteristic.

2. *Ammonium sulphide.*—Nessler's reagent causes a black colour to appear; nitro-prusside of sodium creates a violet colour; odour characteristic, *i.e.*, that of rotten eggs predominates, but a deep sniff will always also detect the presence of the ammonia.

C. *If the litmus is not affected** (*i.e.*, the gas is apparently neutral), it is either :—

1. *Sulphuretted hydrogen.*—Lead acetate papers suspended in the jar are darkened, as are also solutions of lead, iron, or copper salts; odour characteristic.
2. *Carbon bisulphide.*—A highly inflammable vapour with a garlicky odour; the condensed liquid burns with a yellow flame, giving off sulphur fumes, and leaving a yellow deposit of sulphur behind.

D. *If the litmus papers are slowly bleached*, the gas is :—

1. *Chlorine.*—Filtering paper moistened in a solution of potassium iodide and suspended in the jar is first darkened and then bleached; odour characteristic.

Note.—Sulphuretted hydrogen has many reactions in common with ammonium sulphide, *i.e.*, both gases will darken lead acetate papers and solutions of lead, copper or iron salts, and their odours are closely similar; but they may be readily told apart if attention is paid to the subjoined differences :—

Ammonium sulphide.—Alkaline reaction; creates a violet colour with solutions of nitro-prusside of sodium;† odour of rotten eggs and ammonia.

Sulphuretted hydrogen.—Neutral reaction; no effect upon the nitro-prusside; odour of rotten eggs alone.

* If neither acid or alkaline, no water should be added to the air-jar.

† This reaction is only got from alkaline sulphides.

Two of Glaisher's Tables.

Table I.—Factors by which it is necessary to multiply the excess of the reading of the dry thermometer over that of wet, to give the excess of the temperature of the air above that of the dew point—for every degree of air temperature from 32° to 75°.

Reading of Dry Bulb Ther.	Factor.	Reading of Dry Bulb Ther.	Factor.
Degree.		Degree.	
32	3·32	54	1·98
33	3·01	55	1·96
34	2·77	56	1·94
35	2·60	57	1·92
36	2·50	58	1·90
37	2·42	59	1·89
38	2·36	60	1·88
39	2·32	61	1·87
40	2·29	62	1·86
41	2·26	63	1·85
42	2·23	64	1·83
43	2·20	65	1·82
44	2·18	66	1·81
45	2·16	67	1·80
46	2·14	68	1·79
47	2·12	69	1·78
48	2·10	70	1·77
49	2·08	71	1·76
50	2·06	72	1·75
51	2·04	73	1·74
52	2·02	74	1·73
53	2·00	75	1·72

TABLE II.—Showing the weight in grains of a cubic foot of vapour (*i.e.*, grains of vapour to saturate a cubic foot of dry air), under the pressure of 30 inches of mercury—for every degree of temperature from 32° to 75°.

TEMPERATURE FAHR.	WEIGHT IN GRS. OF A CUBIC FOOT OF VAPOUR.	TEMPERATURE FAHR.	WEIGHT IN GRS. OF A CUBIC FOOT OF VAPOUR.
Degree.	Grains.	Degree.	Grains.
32	2·13	54	4·71
33	2·21	55	4·87
34	2·30	56	5·04
35	2·39	57	5·21
36	2·48	58	5·39
37	2·57	59	5·58
38	2·66	60	5·77
39	2·76	61	5·97
40	2·86	62	6·17
41	2·97	63	6·38
42	3·08	64	6·59
43	3·20	65	6·81
44	3·32	66	7·04
45	3·44	67	7·27
46	3·56	68	7·51
47	3·69	69	7·76
48	3·82	70	8·01
49	3·96	71	8·27
50	4·10	72	8·54
51	4·24	73	8·82
52	4·39	74	9·10
53	4·55	75	9·39

PART IV.

COAL GAS ANALYSIS.

CHAPTER I.

The Composition and Analysis of Coal Gas.

As it issues from the retort, crude coal gas—the volatile product of the destructive distillation of coal—contains large quantities of "impurities," in the form of water, tarry matters, ammonia, carbonic acid, sulphuretted hydrogen and carbon bisulphide; and it is therefore necessary to effect considerable purification. This is done by passing it through *condensers*, which remove most of the watery vapour and tarry matters, and some of the ammonia (absorbed by the condensed vapour); through *scrubbers*, which remove the remaining ammonia and tarry matters; through *lime purifiers*, for the removal of carbonic acid; and lastly, through purifiers of an iron salt (generally an oxide) for the abstraction of sulphuretted hydrogen—a sulphide of the metal being formed. Where carbon bisulphide has to be removed, a small purifier of calcium sulphide is used—with the result that a sulpho-carbonate is formed.

A volumetric analysis of coal gas (by Bunsen, Heidelberg).

Hydrogen	46·2
Marsh gas (CH_4) or "light carburetted hydrogen"	34·02
Carbonic oxide*	8·88
Carbonic acid	3·01
Ethylene (C_2H_4) or "olefiant gas," or "heavy carburetted hydrogen"	2·55
Nitrogen	2·15
Benzene	1·33
Propylene	1·21
Oxygen	0·65
Minute traces of napthalene	—
	100·00

Coal gas is thus seen to be a compound gas, consisting of illuminants, dilaents, and impurities (*i.e.*, carbonic acid, sulphuretted hydrogen and other sulphur compounds).

The illuminants are the benzene, propylene, napthalene, and ethylene.

The hydrogen, marsh gas, and carbonic oxide, dilute these illuminants, and themselves burn without creating luminosity—though furnishing heat. The composition of "pure" coal gas must vary in every case, of course, according to the efficiency of the means taken to purify the crude gas, but an average of the London companies would be about :—

Hydrogen	45
Marsh gas	35
Carbonic oxide	7

* Carbonic oxide has been estimated as high as 11 per cent.

Illuminants	6 (ethylene = 3)
Carbonic acid	3
Nitrogen	2
Sulphurous acid, Sulphuretted hydrogen, Carbon bisulphide, Ammonium sulphide	2

In "gas" which has been but little purified, traces of many complex substances may be present, (mostly alcohols and hydrocarbons) but neither their importance or frequency of occurrence is such as to make their inclusion here desirable.

Professor Roscoe found the following differences in channel and coal gas :—

	Hydrogen.	Marsh gas.	Carbonic oxide.	Heavy hydrocarbons.	Nitrogen, carbonic acid and oxygen.
Channel gas	25·82	51·20	7·85	13·06	2·07
Coal gas	47·60	41·53	7·82	3·05	

After combustion the following changes have occurred in coal gas :—

Nitrogen	67
Water	16
Carbonic acid	7
Carbonic oxide, variable, and least when combustion is most complete; generally about	5 to 6
Sulphurous acid, Ammonia, &c.	4

One volume of coal gas uses up the oxygen of from 6 to 8 volumes of air in complete combustion, and produces about 2 volumes of carbonic acid; and each cubic foot burnt furnishes 0·2 to 0·5 grains of sulphurous acid.

The Analysis.

It is beyond our purpose to go into the matter of a complete analysis of coal gas; what concerns us mainly is to learn whether it is sufficiently purified that the products of its combustion shall not yield injurious amounts of harmful gases such as sulphuretted hydrogen and other sulphur compounds, &c., to the atmosphere of our rooms, and also whether the illuminating power it supplies is constantly efficient. The value of the estimation of the sulphur compounds is of especial hygienic import, and Professor Corfield has pointed out that when coal gas gains admittance to the atmosphere, in constant though small quantities - as from defects in pipes or burners - people breathing this atmosphere are apt to contract relaxed and ulcerated conditions of the throat, due in all probability to the sulphur compounds which are added to the atmosphere by the escaping gas.

Another possible source of such air pollution resides in the fact that coal gas can frequently be detected, in small quantities, in the ground air collected from the earth adjacent to gas pipes; and there is no doubt that the gas has the power, in these cases, of passing, under favourable conditions, through the pipes in small quantities. When the escape is in large quantities, into an atmosphere more or less confined, the result may be fatal to those breathing it; this fact is due chiefly to the large amount of carbonic oxide which thus gains access to the air, and the symptoms are accordingly those of poisoning by this agent.

The Gaseous Compounds of Sulphur.

The sulphur in coal gas has been estimated as high as 60 grains in 100 cubic feet of gas; but its amount will necessarily vary with the pyrites in the coal employed, the manufacture of the gas, and the efficiency with which provision for purification is made and maintained. The sulphur is mainly in the form of sulphuretted hydrogen, sulphurous acid, and carbon bisulphide.

Sulphuretted hydrogen.—This harmful constituent of crude coal gas (of which it may form as much as 1000 grains in 100 cubic feet) can be so easily and thoroughly removed by the employment of efficient purifiers, that there is no excuse for its presence in the gas as supplied to consumers. By Acts of Parliament all gas supplied must be wholly free from this impurity; a quantitative estimation, therefore, is unnecessary, since any trace suffices to condemn the gas.

In making a qualitative determination the Gas Referees recommend that the gas should be passed, as it leaves the service pipe, through an apparatus (figure 39),* in which are suspended slips of bibulous paper impregnated with the basic acetate of lead (1 part of sugar of lead to 8-9 parts of water). Such papers become darkened in the presence of sulphuretted hydrogen, &c., in degree varying with the amount of this agent present; the faintest indication will generally be found in a slight discoloration of the extreme margin of the papers.

Sulphurous acid, and sulphur compounds other than sul-

* For the illustrations of apparatus required in gas analysis, I am indebted to William Sugg and Co., Gas Engineers, London.

phuretted hydrogen.—These are estimated by collecting the sulphur as sulphuric acid, into which it is converted by combustion; precipitating this by baric chloride as the sulphate of baryta, and then estimating the sulphur in the precipitate (of $BaSO_4$).

The gas is passed through a *meter*, by means of which the rate of flow can be adjusted and registered to half a cubic foot per hour, and in which a self-acting move-

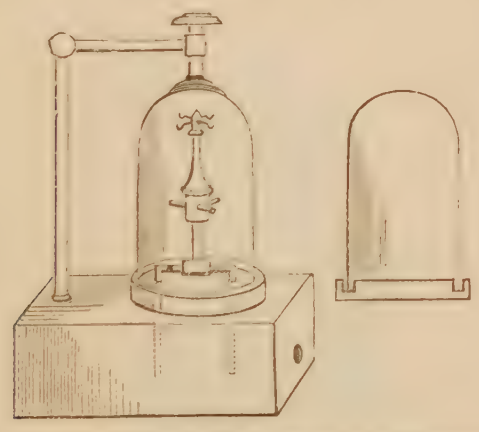


FIG. 39.—Apparatus for testing the presence of sulphuretted hydrogen.

ment shuts off the gas when 10 cubic feet have passed through. The meter employed is shown in figure 40. The dial of the meter is divided into 100 parts, and each complete revolution of the index hand represents that one cubic foot of gas has passed through the apparatus; and each division, therefore, represents $\frac{1}{100}$ of a cubic foot. The position of the long index hand on the dial must, accordingly, be carefully noted at the commencement of each test.

When making the estimation no other gas should be burning in the same room, and, according to the directions of the Referees, the gas (which has been freed from sulphuretted hydrogen) is to be burnt in a small Bunsen burner mounted upon a short cylindrical stand (figs. 41 and 42), perforated with holes for the admission of air (which is necessary to support combustion), and which has, on its upper surface, a deep circular channel to receive the wide end of a trumpet-shaped glass tube. On

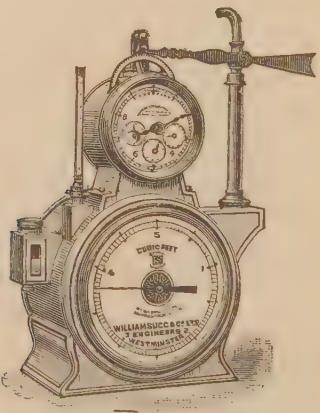


Fig. 40.—The experimental "gas" meter.

the top of the stand, between the narrow stem of the burner and the surrounding glass tube, are to be placed pieces of commercial sesqui-carbonate of ammonia weighing in all about 2 oz.

The products, both of the combustion of the gas and of the gradual volatilisation of the ammonia, go upwards through the trumpet-tube into a vertical glass cylinder packed with glass balls (to break up the current and promote condensation); from the top of this cylinder

a long glass pipe issues, and serves to effect some further condensation, as well as to regulate the draught and afford an exit to the non-condensable gases. In the bottom of the cylinder is fixed a small glass tube, through which the condensed liquid arising from the combustion of the hydrogen in the gas (and containing the sulphuric acid) passes into a beaker placed beneath.

All parts of the apparatus must of course fit accurately, and the india-rubber connections must permit of no escape. The gas flame, which should not be luminous, is of necessity very low indeed—since only half a cubic foot per hour is burnt; and when 10 cubic feet of gas have passed through, the cylinder and trumpet-tube are to be well washed with distilled water, and these

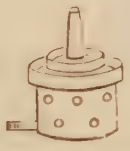


Fig. 41.—Burner with fittings used for estimating sulphur compounds.

washings are added to and mixed with the contents of the beaker. Fresh pieces of sesqui-carbonate of ammonia are to be used for each test. Slight excess of hydrochloric acid, followed by an excess of a solution of the chloride of barium, are next added to the whole which is then well boiled for five minutes. The precipitate of sulphate of baryta which has formed must be collected on a Swedish filter paper, and then several quantities of hot distilled water passed through the filter—so that it may be thoroughly freed of any baric chloride and ammonium chloride remaining behind with the

baric sulphate. This "washing" is repeated, therefore, until a drop of a solution of silver nitrate, added to the filtrate in a test-tube, gives no cloudiness. The filter paper, with its contained baric sulphate, has then to be dried in the water oven; and afterwards folded up

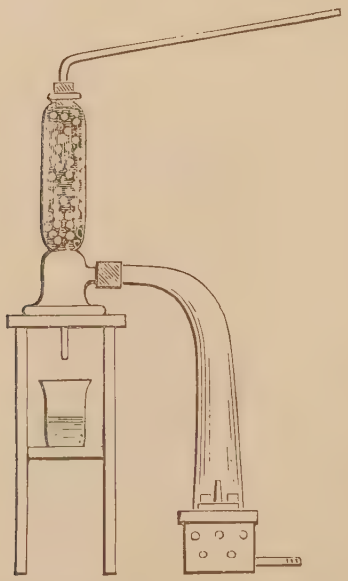


FIG. 42.—Complete apparatus for estimating the sulphur compounds in coal gas.

and placed within a weighed platinum dish, which is then gradually heated to redness, and retained thus until the filter paper has burnt off (*i.e.*, no dark specks, &c., remain). Then the platinum dish is allowed to cool in a desiccator over strong sulphuric acid, and

subsequently weighed. The excess of this weight over that of the empty dish is due to baric sulphate.

Now the atomic weight of barium = 137.

" " " sulphur = 32.

" " " oxygen = 16.

∴ the combining weight of the compound ($BaSO_4$) = 233, of which S = 32. ∴ the sulphur forms $\frac{32}{233}$ of $BaSO_4$, *i.e.*, 0·137.

∴ Supposing 8·6 grains of baric sulphate are found in 10 cubic feet of gas, then 8·6 × 0·137 will represent 1·178 grains of sulphur in 10 cubic feet, or 11·78 grains in 100 cubic feet.

The number is to be corrected for the variations of temperature and atmospheric pressure, in the same manner as that of the illuminating power (*quod vide*)—except that the readings of the thermometer and barometer are to be taken for the day on which the testing commenced, and also the day on which it closed, and the mean of the two is to be used.

The maximum permissible amount is 17 (22 in the winter) grains of sulphur in every 100 cubic feet of gas (Gas Referees).

Ammonia.—Traces of this gas may escape absorption by the water in "the hydraulic main," and the "scrubbers" through which it subsequently passes. This agent besides adding an impurity to the atmosphere, acts deleteriously upon many of the metallic fittings, &c., about a room. Its presence may be detected by exposing to the "gas" a filtering paper, dipped in the Nessler reagent, and noting any degree of yellowing which may ensue. It is necessary, however, to make a quantitative examination; and the Gas Referees recommend that the coal gas should be passed through a glass cylinder (fig. 43) filled with glass beads which

have been moistened with a measured quantity (considerably in excess of any quantity of ammonia likely to be present) of standard sulphuric acid, 25 septems of which will neutralise one grain of ammonia. One terminal tube of the cylinder is connected with the "gas" supply, and the other with the meter; and the "gas" is to be passed through at the rate of about half a cubic foot per hour for 20 hours, so that 10 cubic feet of gas shall be examined. The sulphuric acid fixes the ammonia present, and its acidity is thereby correspondingly decreased. The glass cylinder and its contents are washed out with neutral distilled water, the washings coloured with litmus and tested by a solution of ammonia (100 septems of which contain one grain of ammonia) until the colour changes:—*i.e.*, until the whole of the sulphuric acid has been neutralised. 100 septems of the standard ammonia solution exactly neutralise 25 of the acid; note, therefore, how much of the 100 septems of the ammonia solution employed remain in the burette after complete neutralisation has been effected, and this represents the degree of neutralisation brought about by the ammonia in the "gas." Suppose 20 septems remain;—then, since 100 contain 1 grain of ammonia, 20 contain $\frac{1}{5}$ grain; and ∴ 10 cubic feet of "gas" contain $\frac{1}{5}$ grain, or 100 contain 2.

Fig. 43.—Apparatus for estimating ammonia.

The maximum amount of this impurity shall be 4 grains per 100 cubic feet (Gas Referees).

The illuminating power.—This is ascertained by a

simple method of comparing the light furnished by the gas, burning at a certain rate (*i.e.*, 5 cubic feet per hour), with that furnished by sperm candles, burning at the rate of 120 grains per hour. The meter employed to measure the rate at which the gas is issuing is slightly different from the one mentioned above. There are two hands upon the dial, the position of which are carefully noted at the time of commencing the test. The dial is divided into 50 divisions, and each complete revolution represents $\frac{1}{10}$ cubic foot; each division, therefore, represents $\frac{1}{500}$ cubic foot.

The illuminating power of gas is tested by means of an instrument termed a *photometer*, by which the intensity of the light of the gas flame is compared with that of sperm candles. In Bunsen's photometer the two lights are placed on either side of a screen of white paper, which has a round spot of grease in the middle; the gas light is a fixture, but the candle light can be moved towards the screen, until the transparent spot, as reflected onto a small mirror immediately on either side of the screen, is invisible on either side. Another method of photometry is that of comparing the intensity of the two shadows cast by the different lights.

The intensities of the two lights differ as the squares of their distances from the screen.

The following *notifications of the Metropolitan Gas Referees* are valuable:—

The testings for *illuminating power* shall be three in number, daily; to be taken at intervals of not less than one hour.

The gas in the photometer is to be kept burning for at least 15 minutes before any testing is made.

A clean chimney is to be placed on the burner before each testing.

The candles should be sperm candles, 6 to the pound, each burning 120 grains an hour. Two of these candles shall be used together, and the 3 testings made on one day shall be made with 3 different pairs of candles.

Each testing shall consist of an average taken of 10 observations of the photometer, made at intervals of one minute.

The rate of burning of the gas in each burner shall be 5 cubic feet per hour (shown by the long hand of the meter making exactly one revolution per minute for several minutes consecutively).

The candles are to be lighted at least 10 minutes before the beginning of each testing—so as to have attained their normal rate of burning.

Before and after making each testing the Gas Examiner shall counterpoise the candles; and if the rate of consumption per candle shall not have exceeded 126 grains per hour or fallen short of 114 grains per hour, he shall make and record—in a book to be kept for the purpose—the calculations requisite to neutralise the effects of this difference.

If the rate of consumption shall have varied from the prescribed rate beyond the above-named limits: or if the Gas Examiner should observe (during the testing) that the candles are burning irregularly, or that their flames are not exactly between the two plumb lines which mark their true position—then the testing is to be rejected and a fresh one made.

At the time of each testing the Gas Examiner shall observe the temperature of the gas (as shown by the thermometer attached to the meter), and also the height of the barometer—in order that the volume of gas operated on may be corrected to that at the standard pressure (30″) and temperature 60°. (This is facilitated by

using a table of tabular numbers whereby to make the correction).

It must be understood that as the candle light is brought towards the screen of the photometer, a finger registers on a scale the candle light equivalent to the gas—when their shadows are made to correspond.

Recently, instead of candles, a standard light equivalent to ten candles has been introduced; and instead of this light being moved towards the disc, the disc is moved towards the light—which is thus left undisturbed and steady.

The calculations for working out the corrections, &c., in ascertaining the illuminating power of the gas, proceed in the following manner:—Add the observations together, and divide the sum by 10 to get the average; then, as 2 candles are used, multiply by 2, to get the illuminating power of the gas if tried against one candle. Then as the standard rate of consumption of the candles (viz., 120 grains), is to the average number of grains consumed by each per hour, so is the above obtained number to the actual illuminating power. Finally, make the correction for temperature and pressure, by dividing the illuminating power by the tabular number.

For example (taking the tabular number as 1·025):—

Observations 1st minute	=	7·8	candle power
2nd	,,	7·8	,,
3rd	,,	8·1	,,
4th	,,	8·2	,,
5th	,,	8·3	,,
6th	,,	8·5	,,
7th	,,	8·6	,,
8th	,,	8·4	,,
9th	,,	8·3	,,
10th	,,	8·6	,,
		82·6	

10) 82·6

8·26 = average, by 2 candles.
2

16·52 = „ 1 candle.
123 grains* (*i.e.*, consumption by one candle per hour).

4956
3304
1652

Standard consumption = 120) 2031·96

Factor for correcting temperature and pressure = 1·025) 16·933

16·5 = corrected illuminating power of the gas in candles (which represents the illuminating power of good average "gas").

As to the mode of testing the *pressure at which gas is supplied*:—testings of pressure shall be made by unscrewing the governor and burner of one of the ordinary public lamps, and accurately fitting, in their stead, a portable pressure gauge. The difference of level of the water in the two limbs of the gauge is read by means of a sliding scale, the zero of which is made to coincide with the top of the lower column of liquid. From the observed pressure, $\frac{1}{10}$ inch is to be deducted—to correct for the difference between the pressure of gas at the top of the lamp column, and that at which it is supplied in the main.

The Referees' pressure gauge is represented in the

* Consumption of the 2 candles in 10 minutes = 41 grains. ∴ consumption of 1 candle per hour = 123 grains.

accompanying figure 44. Within a lantern, provided with a handle for carrying and feet for resting on the ground, is placed a candle lamp to give light for reading

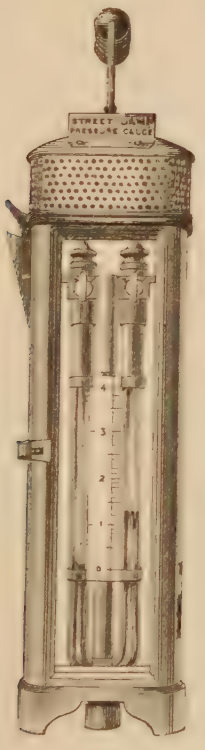


Fig. 44.—The Gas Referees' pressure gauge.

the gauge. In front of the candle lamp is a sheet of opal glass, and in front of this a glass U tube partly filled with coloured water communicates at one end with the air, and at the other with a metal pipe which

passes the bottom of the lantern. In order to read easily and accurately the difference of level of the liquid in the two limbs, a scale, divided into tenths of an inch, is made to slide between them with sufficient friction to retain it in any position. The zero of the scale having been brought level with the surface of the liquid which is pressed upon by the gas, the height above this of the surface which is pressed upon by the air, can be read directly. The lantern is closed in front by a glass door, at each side of which is a reflector for throwing light upon the scale of the gauge. Above each limb of the U tube is a tap which can be closed when the instrument is not in use, so as to prevent the liquid being accidentally spilt.

Carbonic acid does not rank as an impurity—or rather as an injurious contamination—of coal gas; and since its chief effect, when present in quantity, is to limit the illuminating power of the "gas," and this test is specially conducted in all "gas" examinations, the subject does not here call for further comment.

Carbonic oxide.—Every possible effort should be made to rid coal gas from the presence of this very dangerous element, since gas leakages and escapes are of common occurrence in every household. To estimate the amount to which this constituent is present, it should be absorbed by exposing a measured volume of "gas" to the action of a solution of the sub-chloride of copper. The diminution in volume of this "gas," subsequently to each such treatment, is due to the carbonic oxide which has been removed.

Tar.—The "gas" which issues from the retort is very dark, and contains, among its other impurities, a considerable percentage of tarry matter; in the process of purification, however, it becomes quite colourless, and

all but the very faintest indication of tar is removed. Should the purifying process be imperfect in this respect, and tar be present in even slight amount, a piece of white filtering or blotting paper becomes darkened when held in the "gas" as it issues from the burner.

PART V.

FOOD EXAMINATION.

CHAPTER I.

Composition of Cows' Milk.

Milk consists of water, albuminous substances (casein, albumen, and traces of other kindred nitrogenous substances), milk sugar ($C_{12}H_{22}O_{11}$) and mineral salts (chiefly phosphates of calcium, magnesium, and potassium, and chlorides of sodium and potassium; very small quantities of sulphates are present, and traces only of carbonates).

The fat is suspended as minute globules, and since this substance forms the lightest element in the milk, after the lapse of time the bulk of it rises to the surface in the form of "cream"—the largest globules being the first to separate. This natural separation of the fat is a slow process, and even after twenty-four hours is not complete; so that given the cream represented *pure* fat, it would not be fair to take this as representing the total amount of fat which the original milk contained; it is found, moreover, that the cream consists—in addition to fat—of varying proportions of water, sugar, and casein.

If the cream is now separated,* a further change transpires—in a longer or shorter period according to the temperature and the character of the milk—and the result is a souring, followed by a natural separation into a solid ("curd") and a liquid ("whey"). This change can be readily induced artificially by the addition of calves' rennet—but the effect is created naturally by the fermentative conversion of the milk sugar into lactic acid, by the agency of a micro-organism which gains access to the milk, and which is known as the bacterium lactis.

The "curd" is found to consist of casein, albumin, and traces of other kindred nitrogenous substances; the "whey," of the water, milk-sugar and salt.

A still later change is characterised by the appearance of a markedly bluish tint, which is ascribed to the growth of another micro-organism, called bacillus syncyanus; and ultimately the casein decomposes, owing to the access and development of putrefactive bacteria.

"Koumiss" is a well known article, now upon the market, consisting of mares' milk which has been skimmed of some of its cream, and then partially fermented by yeast—whereby much of the sugar, in which mares' milk is rich, is converted into lactic acid.

Cows' milk is, of course, the milk which almost entirely concerns the Public Health Analyst; and when the vast amount consumed, the dependence placed upon it as a food article (forming as it does the staple food of childhood), and the peculiar properties and powers which the medium possesses of absorbing, retaining, and elaborating gaseous and solid poisonous material—

* Milk from which the cream has been separated is termed "skim milk," and such is found to contain only about 0·5 per cent. of fat.

living and dead, organic and inorganic—are considered, the importance of the subject cannot well be over-estimated.

First it is necessary to have a knowledge of the characters of good milk, and a perfect familiarity with his branch of the subject is essential, in order that departures from such may be at once recognised and appreciated.

The average composition of a good sample of pure cows' milk may be given as:—

Fatty solids	3·0	Total solids, 12·5.
Non-fatty solids	8·8	
Ash	0·7	
Water	87·5	
	100·0	

The cream forms about 10 per cent. by volume, and the specific gravity is 1030. The utility, however, of deciding upon an average, is impaired by the fact that milk which has been collected under circumstances which preclude the possibility of any dilution or adulteration, has been found to contain these constituents in amounts varying between considerable limits; so that it is impossible to insist upon the above standard being reached.

The circumstances which mainly determine the quality of the milk are these:—

(*a*) The breed of the cow. Alderneys give most fat, and Longhorns most casein.

(*b*) The time which has been suffered to elapse since the last milking.

(*c*) The stage of milking. That which is first drawn ("fore-milk") contains very little cream (under 0·5 per cent.); but towards the end of the milking, the

cream is very high in amount: and the very last quantities drawn from the udder, and which are known as "the strippings," are almost pure cream.

(*d*) The health of the animal.

(*e*) The age. Young cows secreting less milk—and that of a poorer quality.

(*f*) The time of year.

(*g*) The period which has elapsed since last calving—affecting the presence or absence of colostrum corpuscles.

(*h*) The number of pregnancies—less milk is given with the first calf (Hassall).

(*i*) The food taken—beet and carrots throw up the sugar.

(*j*) The conditions under which the animal is kept—house or grass-fed, &c.

What are the limits, then, within which the various components of a *pure* milk may fall?

I am indebted to Dr. James Bell's valuable manual upon "The Chemistry of Foods" for much information under this head. A large number of milk samples were collected from different cows and examined under his surveillance, and the valuable tables compiled afford a trustworthy answer to the above question. These show that the following limits may be reached:—

Fatty solids, 1·92—6·87 per cent. } Total solids, 10·31
Non-fatty solids, 8*—11·27 ,, } —16·29 per cent.
Mineral ash, 0·62—0·87 ,,
Cream, 2—26 per cent.
Specific gravity, 1026·70—1036·94.

The following table (after Bell) shows a comparison between samples of the milks of various animals.

* It is *very* rare, however, that the non-fatty solids fall below 8·5 per cent.!

Constituents.	Cow.	Woman aged 18.	Woman aged 33.	Mare.	Goat.	Ewe
Specific Gravity . .	1032·50	1034·50	1033·03	1036·12	1032·70	1039·30
Fat	3·76	3·20	2·99	1·76	5·80	11·28
Casein, Albumin, &c.	3·50	2·39	2·51	3·58	4·20	8·83
Sugar	4·75	6·83	6·51	5·87	4·94	3·58
Ash	0·78	0·29	0·30	0·39	1·00	1·09
Water	87·21	87·29	87·66	88·40	84·06	75·22
Total	100·00	100·00	100·00	100·00	100·00	100·00

It will be seen, from this table, how the casein and albumen varied in the samples taken of the different milks, from 2·39 in a young woman, to 8·83 in the ewe; with regard to the fat, how this is lowest in the mare's milk (1·76), and highest in the ewe's (11·28); that sugar ranges from 3·58 in the ewe, to 6·83 in the young woman; and that the water is least in amount in the ewe's milk (75·22), and greatest in that of the mare (88·40).

Adopting the cow's milk as a standard for comparison, *human milk* shows an increased quantity of sugar, and a slightly increased quantity of water; but all solid constituents, with the exception of sugar, are materially less. *Mare's milk* is also richer in sugar and water, and slightly so in casein and albumen; the fat and ash are considerably less. *Goat's milk* is richer in all the solid constituents, and of necessity contains a less percentage of water. *Ewe's milk* is characterised by the very high amount of fat, casein, and albumen; the ash is also higher than in cow's milk, but the sugar and water are less.

The Milk of Diseased Cows.

Although, fortunately, the milk secretion is in abeyance during many diseases, it is not so in all, nor is it even in every case of the same disease; and in a few conditions the milk presents somewhat definite chemical and microscopical characters, which are fairly constant. To the naked eye the milk is commonly all that is desired.

It is in cattle plague, and foot and mouth disease, that these changes are most marked.

In cattle plague the sugar is markedly diminished; the fat is increased, together with—to a less extent—the casein and salts (Gamgee). Blood and pus corpuscles are also commonly detected in the milk.

In foot and mouth disease the milk commonly contains pus, blood, or mucus (*i.e.*, in those cases where there is ulceration of the nipples or abscesses in the udder); and, as in cattle plague, the milk corpuscles, under the microscope are seen to display a tendency to aggregate into grape-like clusters: when the disease is advanced, bodies resembling pus corpuscles (though a little larger), and large yellow granular bodies, together with pus and blood corpuscles, vibriones, and bacteria (the dumbell micrococci of Klein?) are also present. In this disease a chemical analysis varies so considerably in its results as to be of no value for diagnostic purposes. The milk separates, however, remarkably quickly, on the application of a gentle heat, into curds and a pale blue whey; and this feature alone is considered as almost diagnostic by continental observers.

In the Western States of America the cows are sometimes seized with an affection commonly termed "the

trembles," and this is supposed to be caused by their feeding upon the herb "Rhus Toxicodendron." If the milk of these cows be given to children, a train of symptoms sets in, *i.e.*, weakness and prostration, a fall in body temperature, vomiting, swelling and dryness of the tongue, and constipation. Boiling the milk invariably destroys these hurtful qualities.

CHAPTER II.

The Analysis of Milk.

Apparatus required for milk analysis:—

1. Lactometer.
2. Cream tube.
3. Red and blue litmus papers.
4. Three small platinum dishes.
5. Chemical balance, with the set of chemical weights, as described in Part I. ("Water").
6. Pipette graduated in cubic centimetres.
7. Water bath and water oven, on iron stands.
8. Bunsen's burner, with regulator.
9. Crucible tongs.
10. Glass funnel with stand.
11. Packet of cut filtering papers.
12. Microscope.

Reagents:—

1. Methylated ether.
2. Absolute alcohol.

The physical characters:—

1. *Consistence.*—The milk should be quite opaque when placed in a narrow glass tube; otherwise it has probably been watered—whereby it acquires a bluish and abnormally transparent character.

Sometimes it is, on the other hand, thick and viscid; and, on pouring, has an appearance something akin to mucus. Such milk contains large quantities of albumen, and has the property of imparting, when added in small quantities, its own peculiar characteristics to large

bulks of good milk. The condition requires further elucidation.

"Colostrum"—the milk yielded by recently calved cows during the first few days after the birth of the calf—coagulates much more readily than ordinary milk, owing to the much larger quantity of albumin it contains. Some milks, however, coagulate immediately after being drawn, or immediately upon warming; these are, of course, very acid, and are generally yielded by cows in febrile conditions that are suffering from inflammation of the udder.

2. *Colour.*—The colour is greatly caused by the minute fatty globules suspended in the fluid; and everyone has noticed, so soon as these are separated in the form of cream, to what a marked extent the original white colour is lost. Normally a good milk should be white with the faintest possible suspicion of yellow—although such food as buttercups, mangel-wurzel, &c., tend to make the colour distinctly yellow. A distinct yellow may also occur naturally in milk containing considerable quantities of colostrum corpuscles, or where there are certain congestive conditions of the udder. This colour is also sometimes artificially created by dairymen, by means of the addition of annatto or turmeric.

Rarely, the freshly drawn milk is of a faint blue hue—or even green, or reddish-brown; and it is not easy to ascribe a cause for these strange appearances, apart from that furnished by the kind of food consumed; but seeking elsewhere for an explanation, micro-organisms have been adduced as both the cause and the effect. Certain it is that such milks may be deleterious to health, and have, in fact, been known to cause severe gastro-intestinal irritation; and more especially is this the case with "blue" milk. When these colours form

slowly after the milk has been passed, it seems probable that they are then invariably due to fungi—such as oidium lactis or penicillium: and in support of this contention Erdmann discovered that vibriones were capable of producing aniline colours from protein substances.

A pinkish hue is sometimes created by the presence of blood.

3. *Taste and odour.*—No taste or odour—other than that of good milk, with which everyone is familiar—should be perceptible.

Milk has a marked power of absorbing any odorous gases with which it comes in contact, and of acquiring and retaining distinct flavours from the food consumed by the animal secreting it; thus cows which have been feeding upon turnips, yield a milk which tastes strongly of these articles, and when bitter medicines have been administered, or when the chestnut or vine leaves have been eaten, or when the cow suffers from some forms of liver disease,—a bitter flavour is imparted to the milk. Animals, moreover, kept in filthy sheds, and supplied with polluted water for drink, generally furnish a milk which gives some evidence of these facts in its odour.

4. *Reaction.*—This should be neutral or alkaline; and if acid, only *very* faintly so. If markedly acid, most probably lactic acid fermentation has set in; and if markedly alkaline, some alkaline salt (such as sodium carbonate) has generally been added; or either condition may be due to the fact that the cow is not in health.

5. *Sediment.*—Any insoluble solid matter which may have gained access, and is suspended in the milk, is generally readily seen on the white background which the fluid itself presents; and any sediment, even when of

chalk or starch, is always detected at the bottom of the cream tube after the milk has stood in this for several hours.

A *hygienic analysis* of milk essentially aims at the detection of fraud, by making an effort to ascertain how much water has been added, and how much cream has been removed. The addition of such water may also become a weighty consideration to the Health Officer, in connection, more directly, with the purposes of preventative medicine, in those cases where a suspicion of the milk as a probable cause of typhoid, &c., in the district is entertained,—for when such milk is found to be "watered," a judicious and thorough investigation of the source of the water employed, may discover the secret of the milk's infectivity; and the value of the adoption of bacteriological methods, rather than chemical ones, in these cases is apparent.

A hygienic examination of milk, then, must include an estimation of those constituents which will serve to detect the addition of water or of solid matter, or the removal of cream. It is only in rare cases, *i.e.*, in those where the milk is judged to have incurred special risks, or where the consequences of its consumption point to such contamination, that the common poisonous metals (or other *materies morbi*) need be looked for; but it must be borne in mind that milk absorbs metallic poisons with great facility when brought in contact with them, that other *materies morbi* (bacteria, &c.) may gain access in a variety of ways, and that milk is a medium which will feed and foster micro-organisms to an exceptional degree.

The safest lines to proceed upon in forming an opinion of the milk, are—as in water analyses—to draw one's inferences from the results of the many stages of a more

or less complete analysis. If an attempt be made, then, to tabulate in the order of their relative importance, the various means of deciding upon the quality of any sample, and its freedom from sophistication, they may be given thus:—

1. The estimation of the percentage amount of solids —fat.

2. The specific gravity, considered in relation with the amount of cream.

3. The estimation of the solids—non-fat.

4. The estimation and analysis of the ash.

The latter two *estimations*, when taken as a gauge of the quality of milk, may easily mislead if they are only made quantitatively, owing to the fact that mineral salts, starch, treacle, &c., are sometimes fraudulently added; but a qualitative analysis of their *respective constituents* will at once detect such addition. It is useful to hold in view the fact that the ash should in every case be low when the solids—non-fat—are low, and *vice versâ*.

The milk must be fresh, as after lactic acid fermentation of the milk sugar has set in, there is a slight reduction in the weight of the original solids—non-fat; and the sample should in every case be gently shaken before any is removed for analysis.

It will be noted in the analysis, that all the various constituents of the milk, with the exception of the cream, are expressed as the percentage they form by weight of the milk—the cream being expressed by its percentage volume.

1. *The cream.*—Some of the milk is poured into a "cream tube," which is a glass tube similar in shape to a large Nessler glass, and marked into 10 equal parts —the two or three upper parts being further marked

off into tenths; each of these smaller divisions therefore represents 1 per cent. of the whole scale.

The milk is made to stand exactly up to the level of 0 of the scale (due allowance being made for capillarity) and it is then set aside for several hours (8-10), after which time the cream is found to have separated, and its depth is read off by the markings on the cream tube. Supposing the cream is found to extend from 0-10 on the scale, then it is 10 per cent.; and if it extends beyond this to the depth say of 2 of the smaller markings between the 10 and the 20, then there is 12 per cent.—and so on.

FIG. 45. The cream tube.

The cream will have separated in 10 hours sufficiently for the test, and if the time is protracted much beyond this, partial dryness ensues, and the resulting contraction may even leave a space between the lower surface of the cream and the upper surface of the milk, and an error in the reading may be thus easily introduced. The average of good milk shows about 10 per cent. of cream, but the milk of Alderney cows commonly yields between 30 and 40 per cent.

The estimation is of considerable value when considered side by side with the specific gravity (*quod vide*), in forming a rapid conclusion as to whether milk has been tampered with. Unfortunately, however, the whole of the fat does not separate as cream; nor does the amount which separates form a constant ratio to that which remains behind, or otherwise the necessity for some further and troublesome steps in the analysis would be spared.

2. *The specific gravity* is taken by the lactometer, on the

same principles, and with the same precautions, as the reader has learned to employ in taking the specific gravity of urine by the urinometer—that is to say, the instrument must be *accurate*, perfectly at rest when the reading is taken, and floating quite free from the sides of the vessel containing the milk. In taking the height on the stem to which the lactometer floats, it will be seen that, owing to capillarity, the milk immediately around the stem has climbed slightly upward—the extent of this must be allowed for in taking the read-

FIG. 46.—Lactometer and glass, for taking the specific gravity of milk.

ing. A correction for temperature is necessary for exact observation, since the instruments are originally graduated by water (taken as 1000), at the temperature of 60° F., and the specific gravity varies with the temperature. The matter is a simple one, it is only necessary to add or subtract 1 degree of specific gravity for every degree of temperature above or below 60° F.

NOTE.—The specific gravity of distilled water at 60° F. being taken as 1000, that of pure milk at the same temperature is commonly about 1030. This increased

specific gravity of milk, as compared with water, is due to the greater amount of solids it contains. The fat is so much lighter than the remainder of the milk, that with its removal an element is lost which partially counteracts the effects of the more heavy solids it contains, and therefore the specific gravity rises even higher still. A specific gravity above 1032 will create suspicion, then, as to the removal of the lighter element (cream) from the milk; and since the specific gravity test is such a simple and ready one, and is frequently practised by the laity, the dairyman subverts the detection of his fraud by adding something which will lower the specific gravity again, while at the same time it will increase the volume of the milk; water is the agent generally employed! it is cheap, always handy, (if not required too pure), and it is obvious that the specific gravity of water being 1000, the more this is added the nearer will the specific gravity of the mixture of milk and water be reduced to 1000.

Correlatively, an abundance of cream will naturally reduce the specific gravity of a milk; so that a low specific gravity may mean either abundance of cream, or the addition of water.

It follows, then, that the two tests considered together must afford a valuable clue as to the class of milk with which we are dealing, at the very outset of our analysis—since a low specific gravity can only be due to abundance of cream in a good milk. If such cream is very low, the sample is either naturally an extremely poor one, or, what is more likely, water has been added. But from the fact that the fat does not entirely separate, and does so in varying quantities in different samples of milk, it is necessary to proceed further with the analysis before a definite conclusion can be arrived at.

An attempt has been made to estimate the amount of added water, empirically, from the specific gravity; and it has been held that, at 60° F., every fall of 3° in the specific gravity represents an addition of water equivalent to 10 per cent. of the milk. Any such decision would have to include a careful consideration of the cream present at the time, and a low specific gravity (1027) would have to be taken as the standard, to make such a crude test broadly correct.

3. *The total solids and the ash* are estimated in the following manner:—

1. Weigh a small shallow platinum dish.

2. Pour in five c.c. of milk, and then re-weigh, in order to get the weight of milk employed.

3. Evaporate to dryness over the water bath (this will take about two hours).

4. Complete the drying in the water oven, and remove from time to time and weigh, until the weight is found not to vary—at which stage the drying is complete.

5. The weight found, less that of the dish, will be the weight of total solids in the weight of milk employed.

Example.—The platinum dish weighs 7·203 grammes; the platinum dish + 5 c.c. of milk weighs 12·304.

The weight, therefore, of 5 c.c. of milk = 5·101 grammes (*i.e.*, 12·304 − 7·203).

The platinum dish + total solids = 7·900 grammes.

Deduct the weight of the dish (7·203 grammes), and the difference, *i.e.*, 0·697, represents the total solids.

Then there is 0·697 gramme of total solids in 5·101 grammes of milk. This represents (5·101 : 0·697 :: 100 : *x* per cent.) 13·6 per cent.

NOTE.—It is desirable—and it expedites the process—to break up occasionally, with a fine clean glass rod, the film which forms over the milk and delays evaporation.

6. Ignite the total solid residue until all dark specks, &c., have disappeared, and nothing but a perfectly clean white ash remains; this must be effected slowly, and at as low a temperature as possible—and Dr. Bell recommends that an Argand burner be used in preference to a Bunsen, on this account.

The poisonous metals may be taken up, but since milk is only in contact with these for such short periods under ordinary circumstances, it will not be necessary to test for them except in the event of the milk having been boiled in metallic receptacles, or where there are other *special* reasons for suspecting their presence.

7. The ash is then weighed, and its percentage amount by weight ascertained, as in the case of the total solids. Too large a proportion of ash (that is above 7 per cent.), points to the addition of mineral matter; a milk may have, on the other hand, a paucity of ash, due to the copious admixture of water.

8. A rough analysis of the ash is sometimes desirable. It must then be dissolved and tested quantitatively for chlorides, sulphates, phosphates, lime, &c., precisely on the principles detailed under water analysis. Effervescence on the addition of hydrochloric acid denotes adulteration by sodium carbonate or chalk—since the ash of a pure milk does not effervesce when hydrochloric acid is added to it.

9. *Solids—fat and non-fat.*—The estimation of the amount of fat in milk is the corner stone of the whole analytical edifice, for this (and this alone) furnishes *immediate* and *direct evidence* of the quality of the milk.

There are many methods at the present day in use for the extraction and estimation of the fat from milk, and most involve the employment of some especially devised fat-extraction apparatus. The method de-

scribed here, however, is eminently suited to the requirements of sanitary officers, for it is easy and requires no additional apparatus to those already employed. The writer has found this process, after some experience, in every sense a most satisfactory one, and agrees with Dr. Bell, to whose work he was originally indebted for the method, that finer estimations are thereby made than by the use of especially devised fat-extraction apparatus.

The process is as follows:—

1. A shallow platinum dish of about three inches diameter is weighed.

2. And into it are placed 10 c.c. of milk.

3. The whole is reweighed so as to learn the weight of 10 c.c. of milk.

4. Place on a water bath, stirring every now and then with a small clean glass rod (which is left in the dish), until the residue attains the consistence of a tenaceous pulp.

5. If drying has gone too far the solid residue should be moistened, and worked up by the glass rod, with a little absolute alcohol; on the other hand the residue must not be too moist and soft.

6. Half fill the platinum dish with ether, and *thoroughly* mix and pound the residue, by means of the glass rod, so that the ether shall be brought everywhere in contact with the fat which the residue contains.

The ether will dissolve out this fat, and this it does more readily and effectually if it be made hot. A naked flame brought near to the ether will immediately ignite it, so it becomes necessary, in order to effect the warming of the ether, to float the dish and its contents in a little water—heated to the temperature which the fingers can just tolerate for a moment—until the ether boils

gently; then remove, and pour off the supernatant etherial solution of fat onto a small Swedish filter paper, and collect the filtrate in a weighed platinum dish.

7. Repeat this treatment by warm ether three times; or if the residue by then has not acquired a thorough whiteness, or has not been thoroughly broken up into a fine sediment—a fourth time. It is never necessary to to proceed beyond a fourth treatment if each of these has been done thoroughly.

8. Cut off the upper part of the filter and place it with the lower part low down in the glass funnel, then thoroughly wash with ether so as to remove any fat which may have hung about the paper.

9. Place the platinum dish which has collected the filtrate over the water oven, gradually evaporate off the ether, and dry the fatty residue until the weight is found to be constant.

10. The weight, less the weight of the platinum dish, equals the weight of fat in the weight of milk experimented on.

Example.—The weight of the 10 c.c. of milk is found, in the manner already indicated, to be 10·202 grammes.

The weight of the platinum dish for receiving filtrate = 11·009 grammes.

The weight of the platinum dish + fat = 11·349; therefore the weight of fat in 10·202 grammes of milk = (11·349 − 11·009) = 0·34 gramme. How much will this be per cent.?

10·202 : 100 : : 0·34 : x per cent. = 3·3 per cent.

11. The solids—non-fat, are estimated from the residue remaining in the dish from which the fat has been extracted. This is placed on the water bath until apparently dry, and then removed to a water oven kept at 212° F. When the weight is found to be constant,

which will take place in less than an hour, the weight of the dish plus its contents, minus the weight of the dish, will represent the solids—non-fat. This method of estimating the solids—non-fat, is more exact than that of the more ready method of subtracting the fat from the total solids.

An instrument termed the *Lactoscope* forms a ready, but rough, means of estimating the approximate amount of fat which the milk contains. The principle of application of all lactoscopic tests is this:—The greater the amount of fat present in the milk the more opaque the medium, and *vice versâ*.

Into an accurately graduated cylindrical tube of clear colourless glass, 4 c.c. of milk are placed; to this water is added, until certain black lines placed upon a vertical porcelain stem, which rises up in the centre of the cylindrical tube, can be first discerned through the milk. The level of the milk and water is then ascertained by the gradation on the tube, and each such level has been found, by experiment, to correspond to a certain percentage of fat in the milk.

The method is a coarse one, and so far as the medical officer of health is concerned, though it will give him a good clue as to those samples which more especially require analysis, it can never replace the more direct and correct estimation of the fat, as given above.

Microscopic Examination.

A microscopic examination is of great service in detecting smaller amounts of some of the added adulterants, and also in many cases in learning of the condition of the cow yielding the milk—although the

latter is rendered very difficult in the case of dairy samples, which consist of the mixed products of several animals.

Good milk under the microscope consists, as in the accompanying figure, of a collection of round highly refractile oil globules—all of about the same dimensions, with an occasional epithelial cell; and, from 3 to 8 days after calving, colostrum corpuscles are also present in larger or smaller quantities. These latter mostly consist of large yellow cells containing large and small fat globules in their interior, and distinguishable with difficulty from some pus corpuscles which become swollen by the inbibition of milk. Where, however, the animal

Fig. 47.—Milk. Showing the large colostrum corpuscles. (× 250).

is not in health, the following abnormal constituents may also be found:—

Cast of the lacteal tubes, blood corpuscles (which closely resemble those of the human subject), pus corpuscles, and various micro-organisms (*i.e.*, fungi—such as oidium lactis, moulds—such as penicillium, bacteria, and sometimes infusorians). Blood may be detected either by the spectroscope or microscope, or by its chemical reactions; and it will be remembered that an excellent chemical test is the addition of a few drops of the tincture of guiacum and a little solution of peroxide of hydrogen to the suspected liquid, when a blue colour ensues if blood is present. When present in considerable quantities blood tinges the milk, and has a tendency

to settle. Some added adulterants would also be discovered by the microscopic examination, such as the various starch grains, (made more distinct by previously adding iodine), and chalk—this latter consists of irregularly round fragments, frequently showing a double contour, and disappearing with effervescence if a drop of hydrochloric acid is let to run under the cover-glass.

CHAPTER III.

Adulteration.

Milk affords an excellent example of each of the various motives for adulteration, *i.e.*:—1. To increase the bulk and weight of the article—in this case chiefly by the addition of water. 2. To disguise the additions thus made, and to give the substance a false strength and improve its appearance—in this case by salt, cane-sugar, glycerine, &c. 3. To preserve the article—here chiefly to prevent its turning sour, by the addition of carbonate of soda, salicylic and boracic acids.

The dilution with *water* is considerable—indeed, if the milk supply of London were *pure*, the number of cows now employed would doubtless be found thoroughly inadequate to meet our requirements.

How shall we decide then when this fraud has been perpetrated, having consideration for the very great variations which have been found to exist in the strength of milks which have not been tampered with? The question is one which has given rise to a great deal of thought and discussion among analysts, but the difficulties are so great that no satisfactory solution has been found; nevertheless it is clear that the percentage amounts of solids—fatty and non-fatty, will be reduced by such addition of water (though these will retain their normal proportions to each other) and that this fact will afford some clue of any "watering;" more especially, however, would this be the case with the *fatty* solids, since these are not fraudulently added to anything like the same ex-

tent as the non-fatty solids. The whole question as to whether a poor milk is a naturally poor one, or has been made so by the addition of water—important as it is, since unscrupulous dairymen may always considerably water a naturally rich milk and yet not make the sample a poorer one than is sometimes naturally given by some cows—is impossible at the present to decide upon. Special works upon the subject, when dealing with the addition of water, lay great stress upon the amount of the solids—non-fatty, and advise that in all cases a decision should be come to from this estimation. The reason of this is not at first apparent to the reader, for it is easy to detect a fallacy in such a course in those cases where chalk, &c., has been added—as it frequently is—to cover such additions; the estimation of added water is ascertained from the non-fatty solids, however, because the amount of these does not fall (in different samples) so far below the mean as does that of the fatty solids: otherwise, as we have just seen there are strong reasons for preferring an estimation based upon the fatty solids. The calculation is an easy one! Supposing for instance a sample yields 8 per cent. of non-fatty solids. The limit of a very poor pure milk, which is pretty generally agreed upon, is 8·5 per cent., and we are dealing most leniently with the vendor by adopting so low a limit in all cases.

Then if 8·5 per cent. of non-fatty solids denotes 100 per cent. of pure milk what percentage of pure milk will 8 per cent. denote?

$$8{\cdot}5 : 8 :: 100\ \% : x\ \% = \text{about } 94\ \%.$$

Therefore, there is about 94 per cent. of *pure* milk in the sample, and (100 − 94 =) 6 per cent. of water has been added.

Wanklyn is favourable to taking the amount of ash

as a clue to the estimation of the amount of added water, 0·73 per cent. being taken by him as the normal. His standard, however, is probably too high to exclude the risk of injustice being done to the salesman; moreover, there is considerably more scope for error and variation in the results of different operators when estimating an ash, than exists in the preferable method of making an estimation of the non-fatty solids.

Next as to the question of *cream-abstraction*. This of course can only be estimated from the amount of fat present; and the difficulty which meets us at the outset is to fix a fair limit of the amount of fat which every sample should contain. This matter has also been much discussed, and remains unsettled. The limit of the percentage amount of fat which must be insisted upon, whenever this is definitely and authoratively settled, must of necessity be a very low one, in order to include those very poor samples naturally, which contain even less than 2 per cent.; and, in consequence, it is difficult to foresee any measure which shall preclude unprincipled dairymen from diluting rich milk down to this percentage. It is doubtful, therefore, having in view this point, whether it is wise to decide upon a minimum standard of strength, but whether the local circumstances of the breed, food, condition, &c., of the cows should not in every case be used in some measure as a check upon the quality of the milk, consideration being had of the fact, that the milk from the same cow may vary considerably at times, from reasons not yet thoroughly grasped. Dr. Wallace of Glasgow suggests, in this connection, that in every case where the quality falls below a certain standard, the milkman should have the privilege of proving his innocence by having the cow, or cows, milked in the presence of the Inspector or

Analyst; and in the case of a man having, say a dozen cows, it should be no defence for him to show that one of these gives milk of unusually low quality.

If then we can decide definitely upon a fair limit of fat in a pure sample, the amount abstracted by the removal of cream becomes an easy calculation after an estimation of the fat has been made. Suppose that the solids fat have been found to amount to just 2 per cent. Then if we adopt 2·5 per cent. as a very fair limit of the fat in a pure sample, 2·5 per cent. − 2 per cent = 0·5 per cent. at least must have been abstracted; or 2·5 : 2 : : 100 per cent. : x per cent. of the total fat = 20 per cent. of the total fat.

The difficulty of deciding upon the amounts of fatty and non-fatty solids which any sample of milk should contain having already been pointed out, it remains to indicate the broad lines upon which the subject has been approached, in order to decide as to whether the sample should be condemned and action taken against the vendor. It is not fair to the vendor, in every case, to proceed against all samples which fall below a milk of even average quality, nor is it right to the consumer to simply insist that *all* milks should be made to pass only a minimum standard; the question has to be considered in a spirit of fairness and equality towards the vendor and the consumer alike!

It would seem perfectly just, however, to take action in those cases where the fatty solids fall below 2·5 per cent., and the non-fatty solids below 8·5, and where, as a consequence, the specific gravity and the cream fall considerably below their averages; and there appears to be a fairly general tacit consent to these numbers among analysts.

It has been suggested that two standards of quality

should be adopted for all milk—a low and a high one; but the objections to such an adoption are seen, from what has already been said, to lie upon the surface, and to make it highly undesirable—since it would sanction the reduction of good milk to the lower standard, by the addition of water or the removal of cream, both of which are offences against the sale of Food and Drugs' Act, 1875 (*quod vide*).

As milk stands, a certain proportion of the fat rises to the upper layers before it separates so completely as to form a layer of cream, and a defence is sometimes set up by the dairyman, that a poor sample was due to the fact that such upper milk had all been removed, and that the sample was some of the last of the milk in the can. This defence is, in most cases a well recognised subterfuge; and it is, moreover, the duty of the vendor to rouse the milk, and to supply fair samples to one and all alike.

Samples collected on Sunday mornings are generally amongst the poorest, for great inducement is offered to adulteration on these days in order to meet the exceptional demand—due to the fact that the working class more generally indulge in milk upon that day.

The *mineral adulteration* of milk consists chiefly of the following salts:—

1. Common salt. This throws up the amount of ash, and can be estimated by calculating the amount of chlorine in the dissolved ash; when this exceeds 0·14 per cent. (Bell), such addition is at once suspected.

2. Sodium carbonate. Its presence also swells the amount of ash, and this is found to yield considerable effervescence when hydrochloric acid is dropped upon it; whereas if the ash is pure no such effervescence is discernible.

3. Chalk is now rarely added, but it serves to thicken, improve the colour, and also to neutralise acidity. It is best detected in the ash, (which also effervesces with hydrochloric acid), by dissolving this and testing by the oxalate of ammonia.

4. Boracic acid is chiefly added to preserve the milk. A good method of detecting this form of adulteration is that of Kretzschmar. The sample is first well shaken—since calcium borate has a tendency to settle—then 6 c.c. are evaporated down to about one-fourth of the original bulk; a drop or two of strong hydrochloric acid are then added, and as evaporation proceeds a Bunsen flame is directed immediately over the dish. Boron will give a green tinge to this flame.

5. Salicylic acid, like the former, will lend a slight increase to the ash, a solution of which in distilled water gives a purple colour with a drop or two of a solution of the perchloride of iron. A quantitative estimation of this salt can be made by slightly acidulating the milk with hydrochloric acid, and then shaking up with ether in a separator, after which the ether is drawn off and evaporated. The residue is then dissolved in a measured quantity of distilled water, and the amount of colour created by adding a measured quantity of perchloride of iron solution should be titrated,—by taking a similar bulk of pure water, to which the same quantity of the iron solution has been added, and then dropping in a weak standard solution of pure salicylic acid until the colour is matched.

Cane sugar is sometimes added to thicken a poor milk and to slightly sweeten it. This may be tested for by Fehling's solution. Regard must, however, be had to the fact that some sugar (milk sugar) is normally present in the milk. When milk is boiled for 4 minutes

with 5 c.c. of normal sulphuric acid, the increase of sugar over the quantity found before inversion is only equal to about two-tenths per cent., but when cane sugar is present the indications will equal the cane sugar in the milk together with the two-tenths per cent. derived from the altered milk sugar.

Starch is added to thicken poor milk and to disguise its blue colour; treat with iodine and then examine under the microscope, when very small traces will be at once discovered.

Glycerine and treacle are also sometimes added to sweeten and thicken milk. Glycerine is best estimated from the whey, by evaporating this to dryness and freeing from fat by ether; if the residue is thoroughly digested in a mixture of alcohol and ether, the glycerine will be in great part dissolved out by this means. The ether and alcohol are next gently evaporated off, and the glycerine remains as a thick viscid liquid, with no smell and a sweet taste. Heated in a test-tube it decomposes without blackening, and emits acrid fumes (of acrolein).

Annatto or turmeric are yellow colouring agents, added to give the milk a rich yellow appearance. Liquor potassæ will give a brown colour if turmeric be present.

Skimmed milk is sometimes made to look like good rich milk by the addition of "*condensed milk*." An analysis of the ash and non-fatty solids will, however, detect the fraud, since these will be in excess of their general proportions, and the sugar more especially so.

CHAPTER IV.

Butter—Cheese—Tyrotoxicon.

An analysis of butter for sanitary purposes need but rarely proceed beyond a point which decides as to whether a fraudulent attempt is being made to sell such compounds as "oleo-margarine" for pure butter. In the manufacture of oleo-margarine ordinary animal fats* (generally of the ox or sheep) are melted, strained, cooled with ice, worked up with milk, coloured with annatto, and salted; the result is an article very similar in appearance and taste to ordinary butter, and but little inferior in nutritive qualities.

The analysis then—apart from the object of detecting fraud—has no important public health grounds for its performance, and the addition of the ordinary adulterants (water and salt) is of such trivial consequence that there is no necessity to make any effort, as a routine practice, to detect them.

It is opportune before commencing the method of analysis, to first consider the composition of *pure* butter.

A good average butter has the following approximate percentage proportions of its constituents.

Fat, 82 per cent.
Curd (casein), 2 per cent.
Ash, 2 per cent.
Milk sugar, 1 per cent.
Water, 13 per cent.

* In the vegetable kingdoms, the cotton seed oil is most generally employed in the manufacture of spurious butters.

Dr. Bell found, in a great number of genuine samples which he analysed, that the butter-fat may fall as low as 70 per cent., the salts to 0·4, and that the water may vary from 5 to 20 per cent.

The butter-fat is a compound of glycerine with certain fatty acids, and consists of:—

(*a*) The glycerides of certain *volatile* fatty acids, *soluble* in hot water, *i.e.*, principally butyric, but also smaller quantities of caproic, capric, and caprylic acids.

(*b*) The glycerides of certain fatty acids *insoluble* in hot water, *i.e.*, palmitic, stearic, oleic and myristic acids.

There should be very little casein in any sample of pure butter—certainly not more than 3 per cent. It can be readily estimated by weighing, after washing out the salts, the residue left when the fat has been extracted from the total solid residue. The matter is not, however, of great importance.

The same difficulties are met in agreeing upon a standard of quality to which all butters should be made to conform as in the case of milk, since the same causes which effect a considerable difference of quality in genuine milk samples, even from the same animal at different periods, act of course with equal force against the butter formed from such milks.

The Analysis.

It is important to note that after a sample of butter has been seized, it is desirable to proceed with the analysis of it without material delay; and the butter should, moreover, be kept in a cool dark place in the interim of its seizure and analysis, for so soon as it commences to undergo change (decomposition), many of the charac-

teristics which distinguish true butter-fat from other fats tend to disappear to some extent.

The utilisation of other fats in the manufacture of a spurious butter has called for special legislation; the designation of such compounds was originally "butterine," but this term has now been prohibited by law (1887) as one liable to mislead the more ignorant section of the community into the belief that they were buying genuine butter. All foreign fats, therefore, made up to resemble butter, have now to be labeled "margarine," (*vide* Food and Drugs' Act and also the Margarine Act, in Appendix).

Physical Characters:—

These are too well-known to need detailing here; the smell and taste of good butter are familiar to everyone, and are so characteristic that they form in themselves valuable evidence of its purity.

With regard to the colour, the same remarks given in connection with the colour of milk must apply closely to the butter made from it; mention should, however, be made of the fact that annatto is here much more commonly employed as a colouring agent.

We have seen that the main issue of **the analysis** is to determine whether the sample consists of pure butter-fat, an admixture of this with prepared beef-fat, &c., or of this prepared beef-fat, &c., alone. The lines upon which we must proceed to detect fraud, must obviously be those which take advantage of any differences existing in the composition of the two kinds of fat; these differences are mainly the following:—

Butter-Fat.	Beef-Fat, &c.
1. The specific gravity is extremely rarely below 910, and never below 909·8.	Is never above 904.

2. The soluble volatile fatty acids form between 6 and 7 per cent. on an average, and are never below 4·5	Constitute rarely more than half per cent., and never more than three-fourths per cent.
The insoluble fatty acids form about 88 per cent. of its total weight.	Generally about 95 per cent.
3. The melting point of the fat varies from 86° to 94° F., and is commonly from 88° to 91° F.	Rarely, if ever, above 82° F.
4. Readily and completely soluble in ether.	Less so, and leaves a residue.
5. Under the microscope pure butter consists of a collection of small oil globules with an occasional large one, and no crystals except when the fat has been melted.	The contours of the small oil globules are less distinct, and the larger ones are more numerous and irregular in size. Often acicular and stellate crystals of the non-volatile acids are seen.

The specific gravity test is most thoroughly reliable, and suffices in itself for the purposes of detecting fraudulent employment of other fats; it is effected in the following manner:—

1. A quantity of the butter is heated to, and maintained at, about 150° F. in a water-bath—made by placing a smaller beaker containing the butter in a larger beaker containing water.

2. The fat slowly separates—and forms an upper stratum, which rests upon a lower stratum of the water, curd, and salt.

3. In the course of time the upper layer of butter-fat gets clearer and clearer, until at last all the water, curd, and salt having separated, it becomes perfectly clear and transparent. Immediately this has taken place the fat is decanted on to a fine filter, in order to guard against the presence of traces of curd and salt, and the filtrate of pure butter-fat is collected and poured into a

specific gravity bottle. The specific gravity bottle is a small bottle of thin glass, fitted with a glass stopper perforated by a thermometer which registers the temperature of the contained liquids, so that this may be known at the moment of weighing. This bottle must be accurately filled and then stoppered, care being had that no air bubble, or empty space, is allowed to remain between the stopper and the liquid, or the results will be untrue.

4. The temperature at which the fat is poured into the specific gravity bottle is about 110° F., and then the bottle and its contents are transferred to the balance and weighed. The object is to take the weight at 100°

FIG. 48.—A specific gravity flask.

F., and in the time absorbed by the process of weighing, the attached thermometer will, in most cases, have fallen to 100° F.; if not, the operator must delay until that temperature is reached, before taking the final weight.

The weight of the specific gravity bottle when completely filled with distilled water and closely stoppered, at the temperature of 100° F., has been previously estimated, and is known. By a comparison of the respective weights of similar bulks of the two fluids at the same temperature, the specific gravity of the butter-fat is estimated—that of distilled water being taken as 1000,

i.e., $= \frac{\text{The weight of the fat at 100° F.}}{\text{The weight of the water at 100° F.}} \times 1000.$

Notes upon the process.—100° F. is selected as the temperature for weighing because it is the lowest temperature to which it is quite safe to reduce the contents of the bottle, without any solidification of its contents ensuing:—all the fats, animal and vegetable, used as adulterants, remaining liquid at that temperature.

Supposing the specific gravity is found to be 907, then if we take the lowest specific gravity which pure butter may possess as 910, the percentage amount of foreign fat in the sample may be roughly gauged.

910 = The lowest specific gravity of pure butter-fat.

904 = The highest specific gravity of pure foreign fat.

A difference therefore of 6 would certainly constitute 100 per cent of adulteration.

The sample has a specific gravity of 907, and therefore a difference of 3, which will represent (6 : 3 : : 100 : x) 50 per cent. of adulteration.

A valuable means of ascertaining whether the sample is true butter-fat or not, is by direct titration of the amount of potash required to affect saponification.

A gramme of true butter-fat is found to require at least 225 milligrammes of an alcoholic-potash solution for this purpose, so that any amount less than this which suffices, implies the presence of other fats—none of which require as much as 200 milligrammes (oleo-margarine = 195·5).

Kœttstorfer first pointed out this means of detecting adulteration: 2 grammes of the clear fat, obtained in the manner already seen in performing the specific gravity test, are placed in a small beaker, to which 25 c.c. of an alcoholic solution of potash are added. The whole is then gently heated in a water bath, and stirred with a glass rod, until the fat is completely dissolved—

when a watch-glass is placed over the mouth of the beaker, and for 15 minutes such heat is applied as will make the alcohol boil gently. The watch-glass, having been washed in alcohol, is then removed, and the contents of the beaker are well stirred by the glass rod—which should also be washed in alcohol. It then only remains to calculate, from the amount of semi-normal hydrochloric acid necessary to neutralize the potash, how much of this latter has been required for complete saponification of the butter-fat.

The exact stage of neutrality is denoted by an "indicator." Kœttstorfer employed 1 c.c. of an alcoholic solution of phenol-phthalein, which changes from crimson to yellow when an alkaline solution becomes a neutral one.

It must be rare that it is necessary to have resort to any corroborative evidence by the tedious method of estimating the amounts of the soluble and insoluble fatty acids, and under any circumstances where this test is employed, it is not necessary to proceed beyond an estimation of the *soluble* fatty acids—which are more quickly and precisely determined than those which are insoluble. The evidence of the presence of foreign fat which is derivable from the soluble and volatile fatty acids, is undoubtedly best gained by Reichert's process, and this is therefore given to the exclusion of many others, since the writer's preference is supported by many excellent chemical authorities.

The rationale of *Reichert's process* lies in the fact, that the volatile and soluble fats, as has been pointed out, are relatively much higher in butter than in the other animal fats, and that when these are made to yield their corresponding fatty acids, the butyric acid formed from the butyrin is also relatively *much* more volatile than

any of those acids yielded by the ordinary substitutes for butter-fat. If then this volatile fatty acid be separated, the acidity which it creates in the medium containing it, will be considerably greater than any acidity which could be present when other animal fats have been similarly treated; and upon this fact depends the issue of the test.

1. The clear melted butter-fat is collected in the manner described above for obtaining the specific gravity, and then 2·5 grammes of it are weighed in a small glass flask.

2. 20 c.c. of a solution of potassium hydrate in methylated spirit (1 in 20) are then added to the flask, which is next placed in a water bath and gently heated. Soaps are formed by the combination of the fatty acids with the alkali, glycerine is set free and the alcohol is expelled; and the soap should be allowed to form a firm mass at the bottom of the flask.

3. The last traces of alcohol should then be removed from the flask—by sucking the air out through a tube.

4. 50 c.c. of water are next added, and the whole gently heated until the soap is completely dissolved.

5. 20 c.c. of dilute sulphuric acid (1 in 10) are subsequently poured in to decompose the soap, and the fatty acids are thus set free; those soluble in hot water are in solution, while those which are insoluble form an oil upon the surface.

6. The flask is then connected to a small condensing apparatus and the contents boiled slowly—a piece or two of the stem of a clay tobacco pipe being inserted to prevent bumping. The butyric acid is distilled over unchanged; but the distillate also contains some of the insoluble fatty acids, and these must be separated by

allowing the distillate to run through a wet filter before it is finally collected.

7. Exactly 50 c.c. of the filtered distillate are collected, and its acidity is estimated by finding how much of a standard solution of an alkali (soda) is required to effect neutralization—phenol-phthalein being used as an "indicator." 2·5 grammes of pure butter treated in this manner, never yields a less amount of acidity than corresponds to 12 c.c. of decinormal soda solution (4 grammes of real sodic hydrate per litre). If then the acidity is found to correspond to only 10 c.c. of this solution, the percentage of pure butter fat in the sample would be as 12 : 10 : : 100 : x per cent. = 83·3 per cent., or 100—83·3 = 16·7 per cent of foreign fat.

The alcoholic-potash solution when freshly made, should always be subjected to a blank experiment with water, and the amount of alkali then used must be noted—in order that it may be deducted from the amount used in the butter analysis. A check to the extent of 2 c.c. may be necessary with some spirit.

With regard to the *insoluble fatty acids* it is generally admitted that genuine butters contain a percentage of these which may vary from 85·5 to 90 per cent. This difference would permit of the addition of about 40 per cent. of some foreign fats to a very rich milk, without the butter—in respect of these acids—falling below the limit of a genuine sample.

The melting point.—It is recommended that, in applying this test, the butter fat be suddenly cooled by floating it upon iced water in a platinum dish; by this means uniform results are obtained. A little of the fat is then taken up around a clean platinum wire, which is then placed alongside a thermometer in a beaker of

cold water, so that the fat is very near the bulb of the instrument. This beaker is placed inside another larger one also containing water, and thus a water bath is improvised—by means of which the temperature of the water in the smaller beaker can be slowly and uniformly raised by the application of heat to the larger beaker. The temperature recorded by the thermometer at the exact stage at which the fat melts, is that of the "melting point."

The melting points of the different fats vary within narrow limits, owing to the variable quantities of stearin, olein, and volatile fatty acids; and this test, therefore, can never prove *complete* purity, since small amounts of some of the other fats—and even large amount of beef-dripping—would not be detected.

The *salt in butter* may be estimated thus:—

Weigh out 5 grammes of butter into a weighed platinum dish, and place for about two hours over the water bath to drive off water—stirring frequently with a glass rod or the water will not be able to escape. Then extract fat with warm ether, in the manner described in "milk analysis." Dry the residue, dissolve out the salt with warm distilled water, and estimate the amount of sodium chloride from a quantitative estimation of chlorine—performed as in water analysis.

An instrument recently invented by M. Soudén, and termed the "*liquoscope*," will probably come to be employed as a rapid means of detecting adulteration in butter, oils, glycerine, &c. It consists of a glass cylinder containing glycerine, into which two hollow prisms are immersed. When substances with *identical* refractive indices are placed in the prisms, and a black horizontal line upon a white background is looked at

through these, the line appears continuous; but when the substances are of different refractive indices, the line, when thus viewed, appears broken in two—one part being at a higher level than the other.

Microscopic Examination.

Pure butter, under the microscope, is seen to consist of a collection of small round highly refractile oil

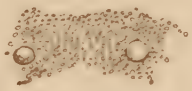


Fig. 49.—Butter-fat. (× 350).

globules, together with a few much larger ones of fairly uniform size. The larger globules average about 6 in number in the field of the microscope at the same time, while the smaller would number many thousands.

In *oleo-margarine* the small oil globules are much less distinct in contour, *i.e.*, they stand out less markedly

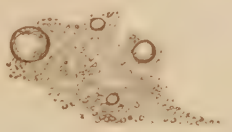


Fig. 50.—Oleo-margarine. (× 350).

than in butter fat and have the appearance of being more crowded together; on the other hand, there is, relatively, a much greater number of the larger globules, some of which reach a much greater size than others, and these do not, in consequence, present the same uniformity as was noted in the case of pure butter.

Adulteration.

Lard, beef mutton and horse fats, together with vegetable oils (linseed, palm and cocoanut), are employed as substitutes of butter fat.

Water is rarely worked into a butter in excessive quantities for fraudulent purposes, since water exceeding about 16 per cent., is decidedly prejudicial to the keeping powers of the butter. Such a practice, however, increases the weight, and is often resorted to in those cases where a ready market is ensured, and the keeping powers of the butter are not, therefore, taxed before sale. Common salt is added to improve the flavour, and also to preserve the butter by checking the decomposition of the casein. It has been found to reach as high as 14 or 15 per cent.; but seeing that its presence in such excess gives a markedly saline taste, it becomes a question of individual palate as to whether such butter is bought and consumed; the point is not one of public health import, and rarely does the percentage amount exceed that which will lend a palatable amount of saltness to the butter, *i.e.*, about 5 or 6 per cent.

The addition of potato or other starch would be best detected by the microscope, after treating with iodine; but these are practically never employed for adulteration purposes.

Annatto, turmeric, and other harmless colouring agents, are commonly used, and C. F. Cassal first pointed out that boric acid was frequently to be found in butter and cream, and that it plays an important part in the composition of the numerous proprietary nostrums sold for preserving these articles.

Cheese.

Cheese consists of the original constituents (chiefly the casein and fat) of the milk from which it is made; but, as the process of ripening proceeds, the sugar becomes changed—chiefly into lactic acid.

The average composition of Stilton,* Gorgonzola, and Dutch cheese—as shown by Bell's analysis, is:—

	Water	Fat.	Casein or nitrogenous matter.	Free acid as lactic acid.	Ash.
Stilton . .	23·57	39·13	32·55	1·24	3·51
Gorgonzola.	31·85	34·34	27·88	1·35	4·58
Dutch . .	41·30	22·78†	28·25	0.57	7·10

There is remarkably little *adulteration* practised in the manufacture of cheese, and the cause is not far to seek, for the article does not readily lend itself to sophistication. For the curd, which is separated from milk by rennet, there is no spurious and cheap substitute which can be made to yield the peculiar characters of pure cheese; there seems, however, a strong probability that lard and animal and vegetable fats may eventually become extensively employed in the manufacture of the cheaper cheeses—so that, by making these replace the abstracted fat (cream) of skimmed milk, this latter may be turned to account.

* Different samples of each of these cheeses vary considerably in the percentage amounts of their constituents.

† Very poor because made from milk which has been partially skimmed.

In this country, at the present day, it may be said that with the exception of colouring matter—which is generally annatto and harmless—the cheeses produced are pure. It has been shown, however, that in some cases (especially foreign cheeses) their surfaces have been brushed over with highly poisonous antiseptic solutions, such as arsenious acid and sulphate of copper—in order to preserve them from attack by parasites and from decay; that colouring matters have also been used to tint the rind; and that those small and delicate cheeses which are wrapped in thin lead papers may take up the metal. A careful examination, therefore, of the rind for metallic poisons may be occasionally desirable.

Fig. 51.—Aspergillus glaucus.

Any starch employed—as it rarely is—as an adulterant, can be detected by the iodine reaction and the microscope.

Cheese is peculiarly liable—and especially the moister kinds—to *parasitic growths*, which are considered by many to add materially to the flavour of the article. They are probably harmless when ingested with the cheese; but a knowledge of the commoner forms of growth is desirable:—

Aspergillus glaucus is a form of vegetable fungus, and gives rise to the appearance popularly known as "blue

mould"—and sometimes also of "green mould"; under the microscope its appearance is that denoted in fig. 51.

FIG. 52.—Mucor Mucedo.

Sporendonema casei is a similar growth, creating the appearance known as "red mould." Mucor mucedo is another fungus which also attacks cheese.

FIG. 53.—The cheese mite. (Acarus Domesticus).

The cheese mite, Acarus domesticus, is a tiny animal parasite shown magnified in fig. 53.

The cheese maggot is an animal parasite of much larger growth ; they are the larvæ of a fly known as "piophila casei," and are readily detected by either the naked eye or by the use of a small hand lens.

Tyrotoxicon.

Milk, cream, butter, cheese and ice-creams, &c., may all rarely contain this poisonous substance, which developes under those circumstances most conducive to fermentative changes generally:—*i.e.*, warmth, impure and confined air, and deficient light. It is a diazobenzene-butyrate, and is found to occur under conditions of improper storage, in the various food articles abovementioned. It will not be necessary, however, to examine these as a *routine* practice for tyrotoxicon ; but when the ingestion of either has given rise to gastro-intestinal disturbances, then a most rigorous search should be instituted for this most powerful poison. The symptoms it creates commonly pass off within a few hours, but occasionally serious consequences have arisen—such as the intervention of symptoms akin to atropine poisoning, and collapse has ushered in death. The general appearance of the milk, &c., is not necessarily altered in any way, but acidity is always marked, and where this is originally present, as in cheese, it is invariably increased.

The *method of examination* if milk be taken, is as follows :—

1. The medium is first rendered a distinctly alkaline one by means of sodium carbonate, then an equal bulk of pure ether is added and the whole well shaken up in a separator.

2. The mixture is next allowed to stand until all the ether is found to have separated into a layer upon the surface.

3. This ethereal layer is then decanted on to a saucer, where it is left until the ether has spontaneously evaporated and a comparatively dry residue remains.

4. The residue is carefully dissolved in a little pure water, and then filtered to free it from fat.

5. The filtrate is next well shaken with an equal bulk of pure ether, and the ethereal layer, having separated, is removed and allowed to again evaporate spontaneously.

6. The residue left upon the saucer will then contain any tyrotoxicon which may have been originally present, sufficiently pure to respond to tests—the best of which is:—

7. Pour on to the residue a few drops of a mixture of equal parts of pure carbolic and sulphuric acids—when, if the poison be present, an orange red or purple colour appears.

In the case of cheese and butter, these are first thoroughly worked up—triturated—with water, which is then treated in the manner indicated above.

CHAPTER V.

Corn—Wheat-flour.

Corn.—This term includes the seeds of cereal plants in general, and it is of primary importance, in food analysis, that the knowledge shall be acquired whereby it becomes possible to distinguish between the different seeds, whether in a whole or ground state.

The appearance of the complete seeds is so generally well known that a description is not required here, and it is, moreover, almost entirely in the form of "flour"—*i.e.*, when these seeds are finely ground,—that the Health Officer is concerned with them. Before, how-

Fig. 54.—The corn Weevil (Calandra granaria). (Magnified and natural size).

ever, dismissing the subject, certain abnormal conditions of the entire seed, which are brought about by small **animal and vegetable parasites,** should be considered.

Those presenting minute round perforations, and consisting almost entirely of a shell, show that the seed has been penetrated and its bulk removed by a small insect, visible to the naked eye, termed *calandra granaria* (*vide* fig. 54) and popularly known as the "weevil."

Those which are discoloured, and in which the bulk of their substance is replaced by a fine cottony material,

have been attacked by the "ear-cockle" or *vibrio tritici*—a small worm-like parasite, pointed at either end as shown in figure 55.

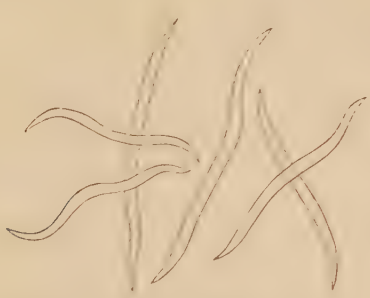


FIG. 55.—Vibriones tritici × about 40.

The *acarus farinæ* is a small microscopic parasite which infests the grain, and closely resembles the acarus scabiei. It especially affects damp and inferior flour;

FIG. 56.—The wheat mite (Acarus farinæ). (× 85).

its characters are shown in figure 56. The eggs of the parasite are oval.

The various *fungi* which attack corn, are the following:—

1. *Oïdium abortifaciens*, or "ergot," most frequently attacks rye ("ergot of rye"), and causes when prevalent in the corn, a condition known as "ergotism" among many of those who habitually consume rye

bread and biscuits. Those seeds which are not absolutely replaced by the fungus are discoloured brown, as is also the flour—which generally has a peculiar sour odour. A microscopic examination shows the characteristic appearances seen in figure 57.

Chemically, its presence in flour is detected by one of three methods :—

(*a*) The flour is made into a paste with a weak solution of liquor potassæ, and then dilute nitric acid is added to slight excess. When the whole is subsequently neutralised by a little more of the

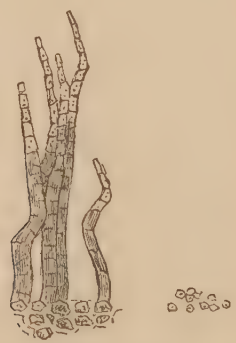


Fig. 57.—Ergot (after Hassall). (× 250).

liquor potassæ, a violet-red colour forms if ergot is present, and a violet colour is established when more of the alkaline solution is added.

(*b*) On the addition of liquor potassæ to the flour, a distinct herring-like odour is appreciable—due to propylamine coming away.

(*c*) The flour is made thoroughly moist with ether, a few drops of dilute sulphuric acid are added, and the whole is then well agitated; on the addition of a few drops of a saturated solution

of sodium bicarbonate a violet colour appears (Hoffman).

2. *Uredo segetum*, "smut," especially affects barley, rye, and oats. The fine dark dust, which sometimes gives the ear of wheat the appearance of having been placed up the chimney, is inodorous, and has suggested the popular name "dust brand" to the condition. Bread made with flour thus affected is bluish.

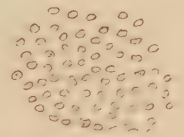


FIG. 58.—Smut spores (Uredo segetum) × about 200.

3. *Uredo fœtida*, "bunt," affects the interior of the seeds of wheat, which it replaces by spores furnishing a fine dust, and hence the condition is sometimes called "pepper brand." The dust when rubbed between the

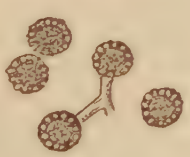


FIG. 59.—Bunt (Uredo fœtida). (× 350).

fingers has a slippery and greasy feel, and gives off a peculiar fœtid smell. No ill effect has been ascribed to the consumption of flour affected with either Uredo fœtida or Uredo segetum. The microscopic appearance of "bunt" is shown in figure 59.

4. *Puccinia graminis* is also known as "rust." The sporangia—as shown in figure 60—consists of dark rounded masses, which either show a double linear

contour or one presenting numerous small projections. The wheat ear and stalk are, when attacked by this fungus, more or less covered by a fine deposit, which has been most aptly designated "rust."

Vibriones appear in flour which is undergoing fermentative changes.

FIG. 60.—Puccinia Graminis × about 200.

THE CONSTITUENTS OF THE COMMON CEREALS.

	WHEAT. (winter-sown).	BARLEY	OATS.	MAIZE.	RYE.	RICE.
Starch*	63·71	63·51	49·78	64·66	61·87	77·66
Nitrogenous matter (*i.e.*, albumin, cerealin, &c.)	15·53	11·46	14·67	14·27	14·87	9·34
Cellulose . . .	3·03	7·28	13·53	1·86	3·23	Traces
Sugar†	2·57	1 34	2·36	1·94	4·30	0·38
Fat.	1·48	1·03	5·14	3·58	1·43	0·19
Mineral matter . .	1·60	2·32	2·66	1·35	1·85	0·28
Moisture. . . .	12·08	13·06	11·86	12·34	12·45	12·15
Total . . .	100·00	100·00	100·00	100·00	100·00	100·00

* The starch includes from 1 to 1·5 per cent. of dextrin, and, together with cellulose and sugar, comprises the carbo-hydrates of the cereals.

† The saccharine body is allied to cane sugar in its reactions.

The numbers in the above table have been taken from Bell's analyses, and it may be pointed out that the results of the analyses of different recognised authorities all differ somewhat, and that sometimes the differences are wide.

It will be seen that barley is—comparatively to wheat—poor in nitrogenous matter and sugar, but rich in cellulose and mineral matter; that oats are exceptionally rich in cellulose and fat, possess a high amount of mineral matter, but are relatively poor in starch; that maize possesses a high amount of fat, but the cellulose is low; that rye is exceptionally rich in sugar, and in other respects closely approximates to wheat; and that rice is rich in starch, but poor in everything else.

Wheat-flour.

The *average* composition of wheat-flour appears, from a large number of samples analysed, to be the following:—

Starch, dextrin, and cellulose	73
Nitrogenous matter*	10·5
Fat	1·5
Mineral matter	0·8
Sugar—corresponding to cane-sugar	0·7
Water	13·5
	100·0

The Analysis.

Physical characters of flour:—The colour should be white, and the flour clean—a yellow hue denotes age or fermentation, and fermenting flour disarranges the

* The nitrogenous matter varies from 8 to 15 per cent., of which gluten forms from 8 to 12 per cent.

digestive system, producing flatulence, dyspepsia, diarrhœa, &c.; there should be no acid or mouldy smell, and practically no taste—certainly none of acidity or mustiness; taken up in the fingers the flour should be smooth, soft and coherent, with no lumpy or gritty feel, and a little flecked on to the wall should mostly adhere; on mixing with a little water, the dough should draw out into stringy masses and knit well together.

There must be complete freedom from fungi and other parasitic growths. There is one great peculiarity in the chemical composition of wheat flour, a peculiarity which arises from the large amount of *crude gluten* it contains; and it is to this substance—or rather to one of its constituents termed "gliadin"—that the characteristic adhesiveness of the flour, which makes it so peculiarly adapted for bread-making, is due.

If flour is made into a dough with water, and then this dough be thoroughly washed, it is this crude gluten which remains as a sticky mass behind; the starch and other soluble substances (*i.e.*, sugar, soluble albumen, and salts) being washed away. It is of great value, therefore, both as a test of the purity and also of the quality of the flour, to estimate the amount of this substance; the best way to effect this is the following:—

Weigh out a quantity of flour—say 50 grammes—place it in a small basin, and carefully mix it with lukewarm water, by means of a glass rod, into the condition of dough; then slowly and thoroughly work up the dough with the fingers, either under water, or while allowing a gentle stream of water to fall upon it. As the dough becomes more and more washed, the water, which is being constantly emptied away and renewed, gets clearer and clearer, and the dough more stringy and sticky. Ultimately all the soluble materials in

the original flour are dissolved out and carried away, and the water escapes in a perfectly clear condition. Nothing then but crude gluten, containing generally a fraction over one per cent. of fat and salts, remains, and the entire absence of starch can be proved by treating with a little iodine. This should then be spread out in a tared (weighed) dish (or a crucible lid is convenient), the gluten dried in the water-oven, and finally weighed.

If the gluten is less that 8 per cent. the flour is not pure wheat flour, and if it cannot be drawn out into long fine threads without breaking, it is poor in quality.

The *water* of flour should not exceed 18 per cent. by weight, since more than this, besides throwing up the weight fraudulently, impairs the keeping power – favouring as it does the development of fungi, and the acetic and lactic acid fermentations, both of which may produce gastro-intestinal disturbances. The amount of moisture is, of course, ascertained by drying a weighed quantity of flour over the water-bath (and subsequently in the water-oven) and noting the loss as due to water.

The *ash* of wheat consists chiefly of phosphate of potassium, magnesium and calcium, but also of salts of silica, sodium and iron, &c.; the total amount should not much exceed 1 per cent.; as much as 2 per cent. would imply that mineral adulterants have been added.

In making the estimation, it is simply a matter of incinerating a weighed quantity of flour in a platinum dish, and then weighing the clean white ash remaining. A short analysis of this can then be made if desirable.

Adulteration.—

The *foreign* mineral matter of flour may also be readily and roughly estimated by shaking up with chloroform—when the flour floats, and most of the added mineral matter settles at the bottom of the vessel.

The process is repeated, in order that it shall be as inclusive as possible, and the sediment is then collected and dried, after which it may be weighed and analysed.

The presence of added minerals (gypsum, &c.) is readily detected in the ash, for this is of necessity found to be exceptionally high; an analysis will disclose the nature of the adulterant.

The question of the addition of alum is dealt with under the heading of bread, since this addition to the flour is most generally made in the process of bread-making; the test there given, however, is of equal applicability to flour.

Recently, in Paris, tin has been found to be commonly present in ginger-breads; its addition appears to allow of the employment of an inferior quality flour in their manufacture.

It is chiefly by the addition of other flours and meals that sophistication is practised, and of course the cheaper varieties are selected—pea, bean, barley and rice are therefore the most extensively employed. It is a question whether in the case of oats, which are of even superior nutritive power to wheat, any addition could be counted as "adulteration"! The seeds of the darnel grass, or Lolium temulentum, are apt to gain access to wheat or oat-flour, either by accident or design; they possess narcotic poisoning properties which render their detection additionally desirable, and unfortunately neither the starch grains or the testa are characteristic—since both resemble oats very closely. The addition of alcohol, however, causes a greenish colour to appear, together with a peculiar repulsive taste, if flour contains these seeds.

CHAPTER VI.

Bread.

Bread is made chiefly from wheat flour, but also from rye, barley, oats, maize and rice; it is to wheaten bread that the following chapter refers.

The composition of good bread (freed from moisture) is roughly as follows:—

Starch, dextrin, &c.	80
Nitrogenous matter	12
Maltose*	5·8
Fat	0·5
Salts	1·7
	100·00

The crumb of new bread contains about 42 per cent. of moisture, and the crust about half this amount.

There are various means now employed for obtaining the porosity of bread; these are harmless and do not concern us here, with, perhaps, the exception of the household method of using baking powders—which consist almost invariably of a mixture of sodium bicarbonate, tartaric acid and rice flour. It is quite a question whether the general use of these chemicals (and impure hydrochloric acid is sometimes used) does not add its quota to the dyspepsia which appears to become more common year by year, and whether their use should not be deprecated.

* In the process of cooking, some of the starch of the wheat-flour is converted into a new saccharine body—allied to cane-sugar, and termed "maltose."

The Analysis.

The bread should be fairly dry, light and spongy (*i.e.*, uniformly occupied by minute empty cells), and no hard cores should be present. It should be clean and of a good colour—nearly white that is to say, for a yellow or dirty colour betrays age and poorness in quality. A peculiar violet tint is given to wheat containing melampyrum and other species of scrophulariaciæ, and trefolium (trefoil); other plants sometimes give the bread a dirty blue appearance (rhinanthus, &c.); agrostemma (corn-cockle) furnishes a greenish tint. Bread must possess a pleasant taste, and should not be sodden, acid or musty.

The general principles of the analysis are similar to those of flour, and it is unnecessary to repeat what has been already given under that heading with regard to the estimation of water and mineral matter. In the case of bread, 10 grammes of the crumbs are a convenient and sufficient amount to work with.

The ash.—The increase in weight of the ash of bread over that of the original flour, is due to the common salt which is added in the process of baking in order to aid the dough rising. Any excess of ash—*i.e.*, above 3 per cent.—is due to added minerals, such as gypsum, chalk, or magnesium salts—added with the object of improving the colour, and increasing the weight of the loaf. The ash is normally neutral, but alkaline if sodium carbonate, &c., have been added.

To estimate the silica, the ash should be treated with strong hydrochloric acid, then a little distilled water, and boiled; next filter the solution through a Swedish filter paper into a small beaker, wash the platinum

dish by boiling more distilled water in it, and filter these washings also into the beaker. The platinum dish being perfectly clean, well wash the filtrate upon the filtering paper with small quantities of hot distilled water; dry the filtrate which is on the filtering paper, in the water-oven, then ignite in a porcelain crucible with lid; finally weigh the ash and deduct the weight of the filter-paper ash—the difference may be calculated as silica.

Adulteration is of the same nature as that of flour, but is carried on to a greater extent, and more especially is this the case with regard to foreign flours—since the process of baking so alters the characters of the starch granules that detection is sometimes impossible. Alum, however, is the adulteration for which it is of most importance to examine the bread.

Mashed potatoes are looked upon as a legitimate addition, in slight amount, where sponginess is dependent upon fermentation, since they favour this action. In large quantity they are added, when cheap, to increase the weight; and since they contain between 70 and 80 per cent. of moisture they help to keep the bread moist.

Pea, bean, &c., starches may sometimes be detected by the microscope, and these would rank in every sense as adulterants, for they are not of equal nutritive value to wheat flour, and they are added either on account of their comparative cheapness, or in order to give weight to the loaf. Pea flour, nevertheless, is rarely added in any but small quantities, or it darkens the bread. If the flour is drenched with boiling water, the presence of pea and bean becomes perceptible to the sense of smell.

Rice when added also serves the purpose of giving a good white colour to the loaf.

Sulphate of copper though formerly employed is probably now *never* used as an adulterant in this country. Its presence could be readily detected by soaking bread crumbs in a solution of the ferrocyanide of potassium, and noting the bronze coloration produced.

Dr. Alford recorded a case of lead-poisoning, affecting from 15-20 persons, arising from the consumption of flour which had been ground by a mill-stone in which large spaces had been filled in with lead.

Microscopic examination.—The starch grains of the flour used in the manufacture of bread become so altered by the process of cooking, on account of the

Fig. 61.—Penicillium Glaucum × about 200.

rupture of their envelopes, as to lose most of their characteristics; and hence, so far as these are concerned, a microscopic examination of the original flour should be made—indeed the whole analysis of flour is so much more easy and satisfactory than that of bread, that an endeavour should always be made to secure samples of the former.

Fungi may be discovered, and notably the different forms of penicillium ("mildew"), which will create, if in quantity, patches of greenish, brownish, or reddish discoloration; oïdium aurantiacum creates an orange hue. These fungi should condemn a bread off-hand,

for they may create serious poisonous symptoms if consumed in considerable quantities.

Alum exists normally, in the pure flour, as the silicate of alumina, and sometimes in considerable quantities; but it is also added to inferior flour, in cooking, so as to check the fermentative action, whereby a large amount of sugar (glucose) is formed and a discoloured bread, unpleasant to the palate, results. Alum thus improves the taste and colour of the bread, and also to some extent its porosity; and it is generally added in quantities of about 15-35 grains to a 4 lb. loaf, but more than 100 grains have been estimated.

It is undoubtedly the most common form of adulteration practised, while at the same time it is the most difficult to detect; at the present day, however, owing to improved processes of bread manufacture, alum is very little employed, and it is comparatively rare that its presence is detected in amounts which denote an excess over that which may be *normally* present. Large quantities of the salt were formerly added to flour, and the great decline in its use commenced with the passing of the Food and Drugs Act, 1875.

It is now pretty generally agreed among physicians, that *no* addition of alum should be countenanced, and that very small amounts, in an article like bread of which such large quantities are consumed, may be deleterious to health, and induce dyspepsia, constipation, &c. It is said, moreover, to reduce the nutritive value of the bread by combining with the phosphoric acid — with the resultant formation of the insoluble aluminium phosphate. There is, however, some diversity of opinion as to whether small quantities of alum are injurious to health, and on this account most of the successful prosecutions under the Sale of Food and

Drugs Act have been taken out under the sixth section of the Act, where the question of injury to health does not arise.

The best *test* for the presence of alum, and one which will detect very small traces (as little as one grain per pound), is the following :—

Reagents required.—1. A strong freshly made tincture of logwood—prepared by digesting 5 grammes of logwood chips in 100 c.c. of strong alcohol. 2. A solution of ammonium carbonate—made by dissolving 15 grammes of ammonium carbonate in 100 c.c. of distilled water.

About 5 c.c. of each of these reagents are added to about one oz. of water, and a piece of the crumb of the bread is cut from the centre of the loaf, and left to soak in this mixture for a few minutes; the fluid is then drained off and the bread gently dried.

The presence of alum is denoted by the appearance of a lavender or violet colour, according to the amount present, while the parts of the bread which contain *no* alum are first stained the bright colour of the logwood solution and afterwards change to a dirty brown tint. Whereas the presence of alum is thus easily and surely detected in small traces by a careful operator, yet considerable difficulty is experienced in estimating its *amount*. If analyses did not dispute the fact that a definite and constant relation might be assumed to exist between the amount of the alumina present and any one of the other mineral constituents of the bread (more especially silica), this might be taken into account, and a ready means of making the estimation could be adopted by computing the amount of one of the more easily separated constituents. No colorimetric test applied to a small portion of the loaf can be considered

as aught but crude and unreliable, since one generally sees the alum unevenly distributed about the bread—that is to say, the mixing with the flour has been roughly executed, with the effect that patches here and there may show a deep blue tinge whereas large areas elsewhere may be free. The operator must be careful, moreover, that he is not led astray—which he often might be if a colorimetric test were adopted—by magnesium salts, which are capable of creating a lavender tinge almost identical with that of alum. The colour created by these salts is certainly not so permanent upon drying as that of alum, but it is difficult in making an analysis to appreciate the true value of this fact and turn it to strict account. For these and other reasons, therefore, it is necessary to resort to the difficult and tedious process of separating the alum, and estimating it by ordinary methods of quantitative analysis. In brief, a weighed quantity of the crumb of bread is evaporated to dryness, incinerated, and the ash treated with hydrochloric acid; precautions having been taken to separate any silica or iron which may be present, the alum is precipitated (and weighed) as phosphate of alumina in the presence of ammonium acetate and excess of acetic acid—the solution being boiled and filtered hot.

When it is considered, however, how unevenly the alum is frequently distributed about the bread, it seems that the only way of achieving an *accurate* estimation, must be by extracting the alum from *the bulk* of the loaf; and more especially is this necessary from the fact that results are generally returned in terms of "grains of alum per loaf." Undoubtedly one of the best methods of separating and estimating the alum in bread is *Bell's modification of Dupré's method*, which can-

not be better given than it is in the work upon "The Chemistry of Foods," by Dr. James Bell.

"One hundred grammes of flour, or the crumb of bread, are carefully incinerated in a platinum capsule over a Bunsen burner, until the ash is nearly white. A quantity of the mixed carbonates of potassium and sodium, known to be free from alumina, in proportion equal to about four times the weight of the ash, is then added, and the whole thoroughly fused. The fused mass is dissolved in excess of hydrochloric acid, and the solution afterwards evaporated to dryness, and gently ignited to render the silica perfectly insoluble. Dilute hydrochloric acid is next added to the residue, which is then heated. The solution is afterwards filtered, and the insoluble silica left on the filter ignited and weighed. To the filtrate ammonia is added until a slight permanent precipitate is produced, which is then redissolved by a few drops of strong hydrochloric acid. A slight excess of acetate of ammonia is next added, and after the appearance of the precipitate has been carefully noted, the mixture is raised to the boiling point, at which it is maintained for a few minutes, and then set aside for several hours. If the appearance of the precipitate becomes more granular during the boiling, or increases very largely in quantity, as will sometimes be the case, it is evident that phosphates of lime and magnesia have been precipitated, and the precipitate must be filtered off, dissolved in a little hydrochloric acid, warmed and reprecipitated as before with acetate of ammonia solution. The precipitate is filtered off, washed, and again dissolved in a small quantity of hydrochloric acid. The solution is boiled for a few minutes with about five grains of bisulphide of soda, and again for a few minutes longer after the

addition of an excess of pure caustic soda. The precipitate of oxide of iron is filtered off, and the filtrate slightly acidified by hydrochloric acid. Acetate of ammonia in slight excess is then added, and the solution raised to the boiling point, and allowed to stand for several hours. The resulting precipitate, which should consist of pure phosphate of alumina, is washed, dried, ignited and weighed. The weight of the precipitate multiplied by 3·873 or 3·702 gives the amount of potash-alum or ammonia-alum respectively, corresponding to the total alumina in the one hundred grammes of flour or bread taken. Before accepting the result as conclusive, care should be taken to prove that the precipitate consists of phosphate of alumina only.

"In this process for estimating alumina as originally proposed, the phosphate of alumina was precipitated in the cold, but in our experiments on flour containing known quantities of alum, it was found that the whole of the alumina of the alum was not precipitated in the cold even after standing overnight, and that the quantity remaining in solution could be recovered by boiling. It is true that by so doing there is increased danger of the precipitate containing phosphates of lime and magnesia, but this contingency is fully provided against by repeating the precipitation in the presence of free acetic acid and subsequent treatment with pure soda."

Conclusions to be drawn from the amount estimated.—If the amount of alum present exceeds from 6 to 10 grains per 4 lb loaf, in the vast majority of cases it has been fraudulently added; some pure flours, however, do undoubtedly contain a greater quantity than this as a normal constituent, and hence it is difficult to lay down any definite and standard quantity beyond which the proof of fraudulent addition may be held to be estab-

lished. The alum which is taken up from the soil is in the form of silicate, and at first sight it would seem that, taken up naturally in this form, it could be estimated from the silica present in the ash. This point would be of great value if it held good, but, as has been already pointed out, analysis shows no definite and constant relation between the silica and the alum of pure flour or bread; nor could such be expected when it is borne in mind that silicates—other than that of alum—may be yielded up by some soils to the cereals growing upon them. If, however, the amount of alum considerably predominates over that of the silica, there is then little doubt of the presence of "added alum." The subject, then, of "added alum" will be seen to be an unsatisfactory and difficult one, from the analysts point of view; and it is fortunate that we are becoming less and less often called upon to estimate its amount.

CHAPTER VII.

THE AVERAGE COMPOSITION OF OTHER CEREALS AND THE PULSES.*—THE MICROSCOPIC CHARACTERS OF THE DIFFERENT STARCH GRANULES.

OATMEAL.

Starch, dextrin and cellulose	63
Nitrogenous matter	16
Fat	6·25
Mineral ash	2
Sugar	1·25
Water	11·5
	100·00

The only common *adulterant* is barley meal. The husks of other cereals are sometimes ground up with the oats, and rice and maize are said to be rarely added also.

ARROWROOT.

Starch, dextrin and cellulose	83
Nitrogenous matter	0·8
Mineral ash	0·2
Water	16
	100·0

When adulteration is practised it is generally by potato, sago, or tapioca starch.

* Chiefly compiled from the results of analysis made by the writer.

Sago.

Starch, dextrin and cellulose	85·05
Nitrogenous matter	0·8
Mineral ash	0·15
Water	14·00
	100·00

The adulterant chiefly used is potato starch.

Tapioca.

Starch, dextrin and cellulose	85·95
Nitrogenous matter	0·55
Mineral ash	0·1
Water	13·4
	100·00

Adulterants.—Potato, sago and rice, are all cheaper, and are sometimes used on this account.

Corn Flour* (Maize).

Starch, dextrin and cellulose	70·5
Nitrogenous matter	9
Fat	4·5
Mineral ash	2
Water	14
	100·0

* Corn flour consists of the nearly pure starch of maize or rice.

Lentil Flour.

Starch, dextrin and cellulose	59
Nitrogenous matter	26·5
Fat	2
Mineral ash	2·5
Water	10
	100·0

This is too cheap to make adulteration profitable.

Pea Meal.

Starch, dextrin and cellulose	58
Nitrogenous matter	25
Fat	3
Mineral ash	2·5
Water	11·5
	100·0

Bean (Haricot) Meal.

Starch, dextrin and cellulose	57·5
Nitrogenous matter	26·25
Fat	2·5
Mineral ash	2·25
Water	11·5
	100·00

Rye Meal.

Starch, dextrin and cellulose	71·25
Nitrogenous matter	11
Fat	2
Mineral ash	1·75
Water	14
	100·00

Barley Meal.

Starch, dextrin and cellulose	72
Nitrogenous matter	11·25
Fat	1·75
Mineral ash	1
Water	14
	100·00

Potato Flour.

Starch, dextrin and cellulose	22·85
Nitrogenous matter	2
Fat	0·15
Mineral ash	1
Water	74
	100·00

The potato juice has an acid reaction, and the ash consists almost entirely of phosphate and carbonate of potassium.

The potato bulb should be firm and resistant to the knife, and show no disease (fungi, &c.). A good test is that of cooking them, and then noting their appearance and taste.

Ground Rice.

Starch, dextrin and cellulose	82
Nitrogenous matter	5
Fat	0·5
Mineral ash	0·5
Water	12
	100·0

The Microscopic Characters of the Different Starch Granules.

The starch, of which the foregoing food-stuffs are mainly composed, exists in the forms of microscopic granules, which are more or less characteristic of the particular plant from which they are derived on account of their different sizes, shapes, and markings. These microscopic granules consist of an extremely thin envelope of cellulose enclosing the starch (granulose), and the latter appears to be arranged in fine superimposed strata—which accounts for the "striæ," or concentric lines, commonly discernible upon the external surface of the granule.

Suppose a sample of any flour or meal is to be examined under the microscope, then a very small amount is placed upon a clean glass slide, a drop of water is applied, and a clean cover-glass is pressed firmly down over the powder and water—in order to evenly distribute the powder and to press out air bubbles. It is impossible to get *too* thin a layer of the substance in order that a satisfactory examination may be made, as otherwise granules get superimposed and conglomerated, and their contours and markings become indistinguishable. It is a good plan, therefore, to drop a small amount of the powder upon the slide and then to gently blow it almost all away again, before applying the water and cover-glass.

It is important that the reader should recognise that in the description which follows, it is the *characteristic* cells which are described in each case. It must not be thought that in a sample of arrowroot, for instance, each granule will possess the characters described

under that head. Such is by no means the case; some may have the hilum in the centre, or even at the small extremity of the granule (as in potato) and yet the sample may be pure. *By far the majority* of the cells will, however, possess in a more or less marked degree, the characters described. Where, therefore, the starch grains of different food plants somewhat closely resemble each other, it is difficult to decide as to whether there may or may not be some admixture, although considerable adulteration admits of no questioning; but when these grains are dissimilar in appearance, the faintest possible amount of admixture is detected by the microscope. When it is required to estimate the *amount* of adulteration in any powdered substance, a rough percentage of the foreign starch grains may be made by counting these upon the microscope "field" of several mounted specimens; and when the percentage amount of foreign starch present has been thus judged, a careful and thorough mixture is made up containing the supposed amounts of the ingredients in the composition under examination, this is then examined under the microscope and compared with the original powder, in order to see if the estimation which has been made is broadly correct. If not, known quantities of the pure substance are mixed with fresh quantities of the adulterants found, until examination shows that the approximately true percentages have been arrived at. Or, to be more accurate, the number of foreign starch granules in the specimen may be counted upon a plan very similar to that adopted in the case of blood-corpuscles—a plan with which the reader is familiar.

It has been seen that, in many cases, the differences between the starch granules are very slight, and some skill is requisite in detecting them; such skill is only

acquired from a steady use of the microscope, and the student is recommended to fit up a small case containing samples of all the more common starches, and to practice assiduously with these; and in order that he may be able to better appreciate the slight differences which distinguish some of the starch granules, it is recommended that a *long* piece of glass slide is employed, so that he may mount upon it specimens of all those which closely resemble each other, and compare them, almost at the same time, by simply moving the slide across the "field" of the microscope. It is useless to make any attempt at mounting these specimens *permanently*, even in glycerine, since they soon lose their characters. A quarter-inch power should be employed, and this suffices for all practical purposes.

Here, space only permits of mention being made of the valuable adjuncts which the polariscope and photography afford to such examinations.

Chemical tests have been proposed, and adopted, as an additional means of detecting some of the starches, but none of these are so reliable as the microscope, and are therefore seldom resorted to. To instance such tests: — bean meal is found to give a deep red reaction with nitric acid followed by liquor ammoniæ, and pure wheat flour, mixed with plenty of water, turns pink with iodine, but any potato starch present changes this to a purple.

1. *Large, round or oval granules, more or less flattened, and showing no marked "striæ"; together with others extremely small and ill-defined.*

May be wheat, barley or rye.

Wheat.—Few, if any, "intermediary"* sizes, although

* A term used, in this connection, to denote a size about *midway* between that of the large and small granules.

the larger granules themselves vary somewhat in size. (A linear hilum and striæ are visible under a high power, and the small granules are seen to be angular).

Barley.—Similar, but whereas the large granules are more uniform in size, they are rather more irregular in shape and somewhat smaller, and "intermediary" sizes

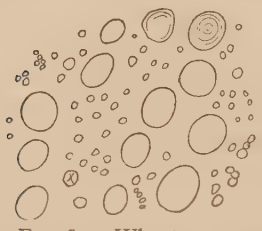


FIG. 62.—Wheat × 200.

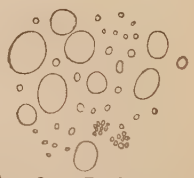


FIG. 63.—Barley × 200.

are more commonly present. Striæ are slightly discernible sometimes in the larger cells.

Rye.—Similar, but many show a rayed hilum and present cracked edges; the granules are somewhat

FIG. 64.—Potato × 200.

larger, and more generally circular and flattened, than those of wheat or barley.

2. *Large, pyriform or oval granules, with well-marked concentric striæ, and a circular or linear hilum.*

May be potato or arrowroot.

Potato.—Typically, they have the appearance of an

oyster-valve. A well marked circular or stellate hilum is at the smaller extremity, and the striæ, starting and ending at the hilum, are well marked. They vary considerably in size.

*Arrowroot.**—Similar, but the hilum is generally at the

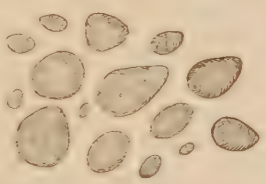


FIG. 65.—Arrowroot × 200.

larger extremity, and the granules average a trifle smaller—with the exception of the arrowroot named "tous-les-mois," in which the granules are commonly even larger than those of potato. The granules do not swell with liquor potassæ as do those of potato.

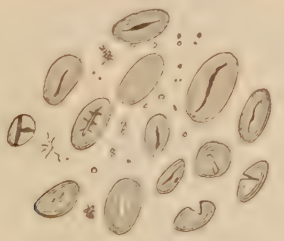


FIG. 66.—Pea × 200.

3. *Ovalish granules, with no concentric striæ, but with a central linear hilum.*

May be pea, bean or maize.

Pea.—Most have a central longitudinal hilum, which

* There are many varieties of arrowroot, all of which, however, present the same general characteristics as to their starch granules; the common variety is derived from Maranta arundinacea.

rarely presents a puckered appearance. The granules are large.

Bean.—Similar, but somewhat larger and more flattened (*i.e.*, broader) and slightly more uniform in size.

Fig. 67.—Bean × 200.

The hilum is much more commonly crossed by transverse lines ("puckered").

Fig. 68.—Bruchus Pisi (of the pea, bean, &c.). (Magnified and natural size).

Maize.—Granules are facetted and much smaller, and

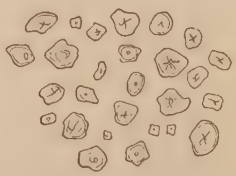


Fig. 69.—Maize × 200.

more irregular in shape—which tends towards the circular. Hilum generally stellate.

4. *Minute, angular and facetted* granules, with no hilum (except under a high power).*

May be rice or oatmeal.

Rice.—The granules collect into angular masses.

FIG. 70.—Rice × 200.

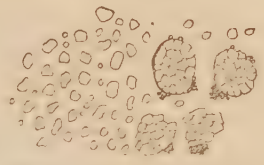


FIG. 71.—Oatmeal × 200.

Oatmeal.—The granules collect into rounded masses, and are slightly larger.

5. *Irregular in size, rounded or with rounded edges, possessing (generally) a central hilum, and showing ill-defined concentric striæ.*

May be sago or tapioca.

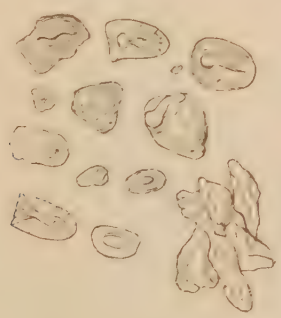


FIG. 72.—Sago × 200.

Sago.—Mostly large, and very irregular in shape; commonly elongated and round at one larger extremity, and truncated at the other. Hilum stellate or linear.

* These facets are due to the close juxtaposition of the granules.

Tapioca.—Similar, but much smaller, and many granules have a tendency to assume the flask-shape. Hilum generally more towards the rounded extremity.

The so-called flours and meals derived from the

FIG. 73.—Tapioca × 200.

cereals, in addition to the starch granules which have been described, also give evidence, here and there upon the "field" of the microscope, of the thin envelope of

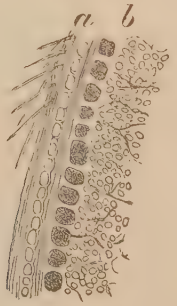


FIG. 74.— Section of wheat grain (outer coat) × 50.
a. Girdle cells. *b*. Cerealin cells.

the grain—called the skin or testa; and this is the case with even the finest ground and purest flours.

In *wheat* the envelope is composed of three* fine

* There are probably six in all under very high powers.

membranes. The external and the middle both consisting of flattened elongated cells, whose contours present a beaded appearance, and which are more or less dove-tailed into each other.

The long axis of the cells in the middle coat are disposed at right angles to those in the external—which are arranged with their long axis corresponding with that of the grain.

The external coat is made up of two or three layers of cells, the middle of only one—and the cells of the latter are smaller and more uniform in size. Unicellular cells ("hairs") with pointed apices, come off in

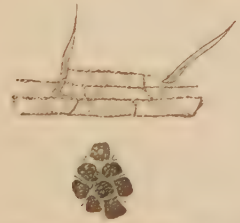


FIG. 75.—WHEAT. Tissue from the "testa" of the grain, showing the appearance of the cells forming its outer and inner membranes. (× 100)

tufts from the external coat at one extremity of the grain; these "hairs" are simply prolongations of the cells.

The internal coat is made up of irregularly rounded opaque-looking cells, which frequently contain one or more oil globules. The starch granules, comprising almost the whole of the interior of the grain, are included within a thick-walled cellular network.

In *barley* the envelopes are similar to those in wheat, except in the following respects:—The cells forming the external coat are smaller and more uniform in size

than in wheat, and their outline is serrated instead of beaded; they carry, moreover, *short thick* hairs. The cells of the middle coat are more elongated, and not beaded—or very imperfectly so. Those of the inner coat are somewhat smaller.

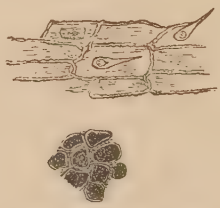


FIG. 76.—BARLEY. Tissue from the "testa" of the grain, showing the appearance of the cells forming its outer and inner membranes. (× 100).

Between the middle and internal coat is a layer of long narrow cells, arranged with their long axis at right angles to those forming the middle coat.

Slight as these differences are, it is to the envelopes

FIG. 77.—RYE. Tissue from the "testa" of the grain, showing the appearance of the cells which form its outer and inner membrane. (× 100).

rather than to the starch granules that one must turn in order to discriminate between wheat and barley.

In *rye* the testa so closely resembles that of wheat that it is difficult to hit upon a point in which they

differ, and it is fortunate that the starch grains afford a ready means of distinguishing between the two.

It may be pointed out that the unicellular hairs are somewhat shorter than in wheat.

In *maize* (Indian corn) the envelopes are two in number; the external consists of several superimposed layers of flattened elongated cells, and the internal of a layer of cells of irregular size and shape, but otherwise resembling the internal layer of wheat. What is very characteristic, however, about maize is that the cellular network, which holds the starch granules, in

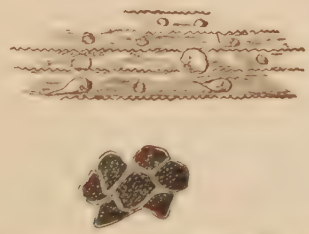


FIG. 78.—OAT. Tissue from the "testa" of the grain. Showing the appearance of the cells which form its outer and inner membranes. (× 100).

this plant forms an irregular mosaic—most often pentagonal but occasionally polygonal in design.

In *oatmeal* the envelopes consist of an external one of long narrow cells with evenly serrated contours (not wavy or beaded), and carrying short sharp spinous "hairs;" a middle, somewhat similar coat, but indistinct and poorly seen; and an inner layer of cells resembling the internal one of wheat, but larger.

In *rice* the external coat of the husk, consisting of long narrow cells, is characterised by the number of fine siliceous particles it contains, and which are col-

lected together into ridges crossing each other at right angles. The spinous hairs are long and numerous, and the other coats, of which there are several, consist also of elongated, narrow, flattened cells, variously arranged.

CHAPTER VIII.

Meat. Parasites of Flesh.

By the provisions of sections 116, 117, 118 and 119 of the Public Health Act, 1875, sanitary officers may examine meat, or carry it away to be dealt with by a justice; and in the vast majority of cases where unsound meat is to be dealt with, proceedings are taken under the above Act; in a few cases, however—as when the flesh of one animal in represented as being that of another—proceedings are taken under section 6 of the Sale of Food and Drugs Act, which provides that "no person shall sell to the prejudice of the purchaser, any article of food which is not of the nature, substance, and quality demanded by such purchaser, under a penalty not exceeding £20."

Section 116 of the Public Health Act is as follows:—"Any medical officer of health or inspector of nuisances may, at all reasonable times, inspect and examine any animal, carcase, meat, &c., exposed for sale or deposited in any place for the purpose of sale, or of preparation for sale, and intended for the food of man; the proof that the same was not exposed or deposited for any such purpose, or was not intended for the food of man, resting with the party charged; and if any such animal, carcase, meat, &c., appears to such medical officer or inspector to be diseased, or unsound, or unwholesome, or unfit for the food of man, he may seize and carry away the same himself or by an assistant, in order to have the same dealt with by a justice."

Section 117 directs that :—"If it appears to the justice, that any animal, carcase, meat, &c., so seized is diseased, or unsound, or unwholesome, or unfit for the food of man, he shall condemn the same, and order it to be destroyed, or so disposed of as to prevent it from being exposed for sale or used for the food of man ; and the person to whom the same belongs, or did belong at the time of exposure for sale, or in whose possession, or on whose premises the same was found, shall be liable to a penalty not exceeding £20, for each piece ; or at the discretion of the justice, without the infliction of a fine, to imprisonment for a term of not more than three months."

Section 118 imposes a penalty against anyone who hinders or obstructs any officer engaged in the performance of his duties in respect of meat examination, &c., and section 119 empowers a justice to grant a warrant for an officer to enter any premises, to search the same, and to seize any article therein which is thought to be unfit for the food of man, in order that it may be dealt with by a justice.

When a piece of suspiciously unwholesome meat has been seized, it becomes necessary for a sanitary official to make a careful examination of such, in order to discover whether it is fit for human consumption. The question is not always an easy one to decide upon, and considerable numbers of poor and diseased animals are killed yearly and consumed, their flesh betraying few, if any, of the characters of bad meat. It is so much more easy to ensure the sale of good meat by even a cursory inspection of the animals before death, than it is by any laboured investigation over a butcher's stall, or in a laboratory, that it may be hoped in the future that the slaughtering of animals will be confined

to public abattoirs, where each animal as it enters is examined in a routine manner by skilled officials. It may be said in this connection, without fear of contradiction, that whereas in almost every other respect our sanitary code in this country is considerably in advance of that of our continental neighbours, yet, in this one respect of the examination and control of living animals prior to slaughter, we fall most lamentably behind them, and that the scant provisions at present made are a disgrace to a country which has grown—with just claims in other respects—to be regarded as having occupied the highest place in sanitary reform during the present century.

In these pages we are concerned alone with the meat as it is exposed for sale, and when a piece has been seized as suspicious, deep sections of the meat should be cut—special care being had to examine that which is more immediately adjacent to the bone.

The Characters of Good Meat.

It should have a marbled appearance—due to little streaks of fat between the muscular fasciculi, and the whole surface should have a glossy appearance, the colour being of a bright florid hue and not too dark—or the meat is that of an old or diseased animal. The colour of veal mutton and pork is always paler than that of beef, and this fact depends to some extent upon natural causes, but mostly upon the fact that calves sheep and pigs are bled at the time of killing. The flesh of all young animals is also naturally paler than that of older ones. Should the meat be very pale and yellow ("white flesh"), and the animal an adult one,

fatty infiltration or degeneration, or fibroid infiltration, is probably the cause. A magenta hue denotes some acute specific condition present at the time of death.

The connective tissues should glisten when exposed, and the muscular fasciculi should not be too large and coarse.

To the touch the meat should be firm and slightly elastic, which implies that the meat is fresh and has set well (rigor mortis); it should, moreover, be so dry upon the surface that the finger is only slightly moistened by being passed over it—such moisture (juice) should be of a clear red colour, and of an acid reaction.

On cutting through a muscle, the whole thickness should present an uniform colour, or the interior must be but very slightly paler than the more external flesh. The odour of meat is best obtained either by drenching it, when finely minced, with very hot water; or by plunging a clean odourless knife deep down into its substance—and preferrably in the direction of bone—and then withdrawing and smelling the knife. The peculiar odour of good fresh meat is familiar to all, both in the raw and cooked state, and any departure from this would create suspicion.

The fat has a firm and greasy feel; the normal faint yellow colour must not be excessive—although the fat of animals fed upon some oil cakes acquires a very distinct yellow hue. The fat deepens in colour with age. It should present no hæmorrhagic points. Butchers sometimes rub melted fat over the flesh of diseased animals, to give it the glossy appearance before mentioned (Gamgee).

Any lymphatic glands attached should be firm, slightly moist, and of a pale greyish yellow appearance on section.

The marrow of the bones should be light red, and that from the bones of the hind quarters should set firmly within 24 hours; but that of the fore quarters remains diffluent for a longer period.

The ash of the meat is alkaline, and consists almost entirely of phosphates and chlorides.

Upon cooking, the fibres do not cook hard, the loss does not exceed 30 per cent. (whereas bad meat containing an undue amount of water may lose over 40 per cent.), and a savoury odour escapes.

Dried upon a water bath for several hours, it does not lose more than 74 per cent. by weight.

The Characters of Bad Meat.

A deep purple or dark tint suggests that the animal has not been killed and bled, but has died with the blood in it, and probably of some acute feverish condition, or else of some pulmonary complaint involving mechanical obstruction to respiration. A yellow or mahogany hue denotes bile-stained flesh.

Well defined and dark coloured areas full of blood, are due to hypostatic congestion, or post-mortem staining.

Pus may be seen lying between the muscle fibres, and tumours, &c., may be present (as in anthrax, &c.).

There is frequently too great a proportion of bone to flesh, and the reaction of the juice (which is dark or discoloured) is alkaline or neutral. The odour may be that of putrefaction, or of a faint and sickly nature. It may be sweet (uræmia), or urinous (due to local effusions of urine).

Sometimes there is a smell of physic, as when, pre-

vious to death, odorous and volatile drugs such as camphor, prussic acid, turpentine, creosote, chloroform, &c., have been administered, or the animal has fed upon odorous plants—or when, subsequent to death, the carcase has been hung in an atmosphere which is odorous from any cause (tobacco, carbolic acid, &c.). The chief dangers to the meat would arise from the administration during life of such drugs as arsenic, antimony (tartar emetic) or strychnine; and if there is any reason for suspecting their presence, some of the meat may be given to a dog or cat, and its effects carefully watched. The animal may in some cases take in poison by its food, by feeding upon such herbs as byrony, meadow-saffron, rhus toxicodendron, &c.

Bad flesh is frequently moist, sodden, flabby and dropsical, and infected with parasites. It must be remembered, however, that the flesh of young animals is always pale and moist.

Some parts of the meat generally feel softer than others, that is to say, there is not an uniform resistance to pressure, and occasionally there may be emphysematous crackling.*

The fat is generably soft and flabby, or gelatinous, frequently highly coloured and exhibiting small hæmorrhagic points.

Any attached lymphatic glands will often be either enlarged, softened, hyperæmic, ecchymosed, caseated, calcified or suppurated. The marrow of the bones is discoloured—often brownish—and sets badly.

In *commencing putrefaction* the flesh softens, and tears readily; it becomes paler; the elastic resistance gradu-

* The flesh of veal and lamb is sometimes blown out artificially, and the surface then smeared with melted fat; an artificial plumpness is thus given to poor meat.

ally diminishes and becomes less uniform, *i.e.*, some parts are softer than others; the characteristic odour is developed; the marrow softens and turns brownish; and the juices become alkaline in reaction. Later, the meat becomes of a greenish hue, and a glance then suffices to detect the presence of putrefaction.

Certain diseases cause distinct, and sometimes characteristic, appearances in the meat—and notably is this the case with anthrax and the anthracoid diseases (quarter ill, &c.); in these the tissues and organs generally are congested, the blood is dark in colour and viscid, ecchymoses and hæmorrhages are frequent and the lymphatics are enlarged and congested; but it is only from an examination of the internal organs that a definite diagnosis can be attempted. When, therefore, any suspicion attaches itself to the sample of meat under examination, every attempt should be made by the Health Officer to penetrate the thicket of difficulties and subterfuge which will beset his path, and to gain a glance at the offal* of the animal in the slaughter-house if not too late, and more especially to carefully inspect the liver, lungs and lymphatics.

The lungs and pleura may be the seat of hepatisation, œdema, infiltration with pus, multiple abscesses, cavities, nodules, &c., and the pleura may be adherent, or contain effusions—in such diseases as pleuro-pneumonia, tuberculosis, pneumo enteritis, anthrax and actinomycosis; a microscopic examination may detect specific germs.

Tuberculosis of the lungs is popularly known as the "pearl disease" or "the grapes," the pearls referring

* The term "offal" includes the head, the feet, the skin, and all internal organs except the kidney. The remainder of the animal is termed the "carcase."

to the tubercular deposits which hang down from the surface of the lungs like grapes. The lymphatic glands of the thorax may be enlarged, caseous, calcareous or purulent.

The liver may be enlarged, tuberculous, softened, congested or bile-stained, and may show hydatids, multiple abscesses, nodules, or the liver fluke, &c., in different diseases (such as tuberculosis, anthrax, parasitic infection, &c.).

The spleen may be enlarged and with rounded edges, or contain nodules or ulcers, &c., in anthrax, glanders, &c.

The lymphatic glands (abdominal) may be enlarged and inflamed, &c., in pig-typhoid (pneumo-enteritis), glanders, small-pox of sheep, swine plague or fever, tuberculosis, &c.

The kidneys may be inflamed and show hæmorrhages, &c., in tuberculosis, swine-fever, &c.

The stomach, intestines and peritoneum may be inflamed, congested or ulcerated, in pneumo-enteritis of the pig, &c., swine plague, cattle plague, anthrax, &c.

The head.—The tongue and mucous membrane of the mouth may show blisters and ulcers, due to foot and mouth disease; the lower jaw, the tumours of actinomycosis; the brain may show hydatids and tuberculosis; the small cysts of trichinæ may be seen in the conjunctiva, or the under surface of the tongue; the nose may be ulcerated and the membrane nodular, from glanders and farcy in the horse, or from small-pox in the sheep.

The skin.—Variola-like eruptions of spots (papules and pustules) may be present; the wool and hair rough and patchy, and showing red blotchy skin beneath.

The udder in cows may show blisters, ulcers, nodules,

&c., in such conditions as foot and mouth disease, tuberculosis, Hendon disease, &c.

The feet may show blisters and ulcers, and the hoofs may be loose and even shed—in foot and mouth disease.

Opinion to be formed.—It is by no means an easy matter to decide as to what shall condemn meat. Opinion at the present day is very much divided upon those diseases which render the flesh of animals attacked by them unfit for human consumption. Most authorities appear, however, to be agreed in condemning the whole of the flesh of animals slaughtered while victims of the following diseases, either on account of the poor quality of the meat, or from its risks of infecting :—

Pyæmia
Septicæmia
Uræmia
Erysipelas
} In those cases where multiple abscesses are fairly general; or where sloughing occurs anywhere about the body, or where putrefaction has set in.

Anthrax and anthracic diseases.
Cattle plague.
Advanced rabies or swine fever.
Glanders or farcy of the horse.
Hydatid diseases.
Variola.
Trichiniasis.
Tuberculosis and cancer, where deposit, &c., is fairly general, and emaciation is marked.

The question as to whether tubercular meat can spread infection to man is still *sub judice*, but there seems little doubt that it has this power, although direct evidence is lacking; if, however, as in trichiniasis, the meat is properly cooked,* this danger is re-

* A temperature of 140° F. is sufficient to kill all forms of hydatids, and 212° F. will kill even anthrax bacilli.

moved—but large joints are rarely cooked through, and the temperature to which the deepest portions of the joint is raised, may often on this account be insufficient to destroy the more resistant infective materials; raw flesh, moreover, is now largely given to infants and invalids. The organs (internal) must in every case be unhesitatingly condemned.

The subject of the spread of tuberculosis through the means of the flesh and milk of tubercular animals, has received of late—as befits its importance—considerable attention. We are indebted to Villemin for first demonstrating the communicability of tuberculosis from animal to animal, but it was reserved for Koch to prove the invariable presence and to describe the characteristics of the specific micro-organism. Subsequent investigators, prominent among whom stand Sims Woodhead, Macfaydean, Watson-Cheyne and Bang—may be said to have established the fact, almost beyond questioning, that the milk and flesh of tuberculous animals may, under favourable conditions, become infective. In the case of milk drawn from udders which are the seat of tubercular lesions, there is no gainsaying its universal powers of infectivity; and where the cow is suffering from general tuberculosis—though the udders may be apparently unaffected—the milk has frequently been shown to also possess infective properties. There is no questioning the strong probability* that much disease may be conveyed to human beings by consuming the flesh of tubercular animals, though no case has been directly proved, and Dr. Newsholme in a recent report has laid great stress upon the likeli-

* Portions of tubercles and cultures of the bacilli have been swallowed by various animals, and many have subsequently developed tuberculosis.

hood of such infection. He points out that the only question now remaining—when the disease affects more than one part of the body—is whether part of the animal or the whole should be condemned. There is no difference of opinion as to the necessity of destroying the parts obviously diseased, but in practice it is very difficult to completely separate diseased from apparently healthy parts. There is no difficulty of opinion, again, as to the necessity for condemning the whole of tuberculous carcases when wasting has occurred. The real question remaining, therefore, is whether in the event of tuberculosis affecting many internal organs, but without having as yet produced wasting of the flesh, the whole or any part of the carcase should be condemned. It is admitted by all that the bacillus tuberculosis may under certain circumstances be taken in by the alimentary canal; the great frequency of mesenteric disease in young children, which is almost certainly derived in a large number of cases from tubercular milk, is an unhappy proof of the last mode of infection. This being so, one is at a loss to understand why comparatively early but widespread tuberculosis, without emaciation, should be less infectious than when accompanied by emaciation.

Birch-Hirschfield and Schmall have lately shown that the bacillus, in travelling from one organ to the other, must pass through the general lymphatic or blood system; and it is impossible to guarantee that at any given time, the flesh through which these are circulating is free from infection, although no lesions have been locally produced. Dr. Newsholme points out that the incidental presence or absence of emaciation is absolutely irrelevant—tuberculosis being an infective disease contaminating the whole animal in either case, and

there will be found few to disagree with him, for the whole of the animal's blood must be infected with the bacilli tuberculosis, and who shall say that no part of the carcase of such an animal may not be given in a perfectly raw condition to infants and invalids?

As to putrefaction, there are many who will not eat certain kinds of meat which have not been suffered to reach advanced stages of this process; there is no doubt, however, that whatever be the peculiar desires and tastes of the consumers, there is no defence for vendors offering any but *fresh* meat *for sale*. In other words, it should be insisted that the meat is *sold* fresh, so that whether it is cooked and eaten as such may be entirely a matter of the individual tastes of the purchasers. There is no doubt that with many, any flesh in which decomposition has only even made a start, entirely disagrees with them; and abundant evidence is not lacking, that when an advanced state of putridity has been reached, violent gastro-intestinal irritation followed by diarrhœa, vomiting and toxic symptoms, are induced—most of which are due to the presence of toxic albumoses and crystallized toxic alkaloids, which are elaborated from the albuminous material.

It is not desirable, in the public interest, to proceed in the matter of condemnation too rigorously, but rather to adopt a standard based upon considerations, which have been carefully studied, as to the actua safety of consumption; for too extensive restrictions, such as those which would include the condemnation of the flesh of those animals dead from all acute feverish conditions, can but have the effect of increasing the cost of a necessary article of diet, which is already almost beyond the reach of the poorest of the community.

Bearing this point in mind, it will be useful to consider what are the means which may be adopted, whereby the meat of animals diseased may be consumed with the minimum amount of risk. Such are :—

a. The animal should be well bled at the time of killing.

b. All internal organs and offal should be destroyed, and all prominent lymphatics removed.

c. The meat should be cut into strips before cooking, so as to insure that the cooking process shall be thorough and there shall be no underdone parts.

d. The meat should not be kept longer than possible, and it may be salted with advantage.

The subject of a microscopic examination is a lengthy one, and the pathology of the morbid tissues of cattle, &c., so closely resembles that of human beings in such common diseases as tuberculosis, pneumonia, pleurisy, &c., that nothing special in this relation need be gone into here—since the reader will be already familiar with the tissue changes, &c., which accompany each of these diseases; nor, indeed, is a microscopic examination in these cases commonly called for, the macroscopic post-mortem examination of the tissues amply sufficing, in the majority of cases, to a diagnosis.

In the case of those diseases dependent upon the presence of specific micro-organisms, a careful microscopic examination is essential, and special bacteriological methods must be adopted in many. The *zymotic diseases* so-called (*i.e.*, pleuro-pneumonia, malignant catarrhal fever, erysipelas, muco-enteritis, influenza, diphtheria, croup, rabies, anthrax and anthracic diseases, rinderpest or cattle plague, foot and mouth disease, swine fever, variola, actinomycosis, tuberculosis

and glanders or farcy of the horse) are all due to the presence of specific micro-organisms.

Of those organisms which are more commonly known as "the parasites of animal tissues," some only are inter-transmissible when the flesh is eaten by human beings, and since the subject, which is a long one, must

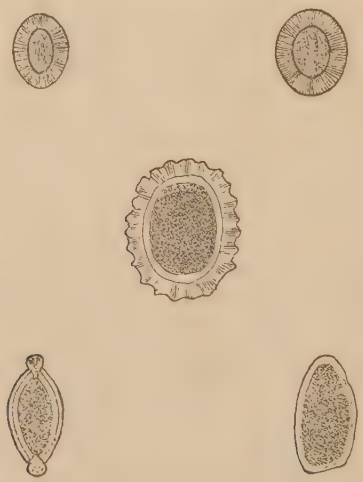


Fig. 79.—The ova of the common human parasites (after Graham Brown).

Tænia Solium. Tænia Mediocanellata.
Ascaris Lumbricoides.
Tricocephalus Dispar. Oxyuris Vermicularis.

necessarily be curtailed here, the salient points of those which authorities are agreed should be regarded with apprehension, will be alone considered, and the following parasites, though commonly present, will not concern us:—*i.e.*, Coccidia oviformes (Leuckart) which infest most animals and chiefly the liver and intestines;

Rainey's capsules,* in the muscle-fibres of animals generally; Tænia echinococcus ("hydatids"), in the lungs, liver, brain, &c., of animals generally; Cœnurus cerebralis, forming hydatids in the nervous system of the ox and sheep; Cysticercus pisiformis is found in the abdominal cavity and liver of the rabbit and hare; Cysticercus tenuicollis in the abdominal cavity of animals generally, *i.e.*, ox, sheep, pig, &c.; Distoma hepaticum or the liver fluke in the liver, and Strongylus filaria in the lungs of sheep; Strongylus micrurus in the lungs of cattle, and Strongylus paradoxicus in the lungs of the pig.

The Important Parasites of Flesh.

Cysticerci.—The cysticercus, or "bladder-worm," causes the condition known as "measles" in the pig, ox, and sheep: and when the flesh thus affected is consumed, the "bladder-worm" undergoes a series of changes, which terminate in its conversion into a *tapeworm*. In *the flesh of the pig* a number of small oval or round cysts are seen, occupying a position between the muscular fasciculi, and commonly varying in size from a pea to a cherry—though they have been found as small as $\frac{1}{25}$ inch, and as large as $\frac{3}{4}$ inch in length. These cysts contain the "cysticerci cellulosæ"—or those bladder-worms which form a stage in the development of Tænia solium—coiled up, and surrounded by a pale milky looking fluid; and the whole cyst shows a white spot (generally central) upon its surface. The affected

* It will be necessary to refer to Rainey's capsules in connection with trichiniasis, and it is thought advisable—from its very common occurrence—to shortly describe the appearance of Distoma hepaticum.

flesh is pale, soft, unduly moist and flabby; and it has a slimy feel. Frequently there is some degree of calcification of the capsule, and the result is that sections are frequently cut with a grating sensation.

The bladders should be incised with a sharp knife,

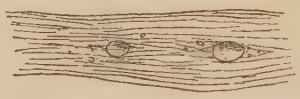


FIG. 80.—"Measly" Pork, showing diagrammatically its appearance by the naked eye.

and the worm examined by a powerful hand-lens—when at one extremity will be found the blunt square head provided with a sucker at each "angle," and a fringe of hooklets placed more centrally; these latter are very characteristic, and must always be found before a definite diagnosis is ventured on.

FIG. 81.—Head of Cyst cercus Cellulosæ × about 40 diameters.

The younger pigs are especially attacked, and during life the earliest evidence is afforded of the parasites, by the presence of one or more small cysts in the conjunctiva, or in the loose tissue of the frænum linguæ. After death the liver, and the muscles of the shoulders intercostals and loins, are seen to be chiefly affected.

The cysticercus of the ox—Cysticercus bovis or "beef-measles"—chiefly affects the calf; it possesses a flat head armed with no hooklets, but simply suckers, around which there is frequently a considerable deposit of pigment. It develops into the adult tape-worm called Tænia mediocanellata, which appears to be more prevalent in this country than Tænia solium.

Trichina spiralis.—This parasite has been found in the flesh of many different animals, but most commonly, by far, in that of pigs; oxen and sheep do not suffer from attack by these nematodes.

FIG. 82.—Trichina Spiralis, encysted in muscle × about 40 diameter.

The shape of the minute worms is nearly that of a typical nematode, *i.e.*, a slender rounded body tapers gradually at either end; the extremity which constitutes the head, goes to a long slender point which presents a small central orifice—the mouth; the other extremity, the tail, ends more bluntly. The worms possess a distinct alimentary canal, and even rudimentary sexual organs are present; in the female an uterus is discernible, which will frequently be seen to be full of minute free embryos curved upon themselves; these

latter have been observed to become extruded from the vagina, and subsequently to move sluggishly about the field of the microscope. The male worm is much smaller than the female, and is only about $\frac{1}{16}$ inch long when mature; the latter reaches $\frac{1}{8}$ inch. The long slender head and blunt tail are two characteristics which serve to distinguish these worms from parasites which otherwise resemble them, such as Dracunculus and Filaria sanguinis hominis.

The small worms are mostly coiled up in cysts, so disposed that their longest diameter is in a line with the muscular fibres. These cysts lie between the muscular fibrillæ, and their walls are sometimes partially or completely calcified—so as to feel quite gritty to the touch; and this calcareous deposit serves to shield the parasites from the destructive consequences of salting, and to a slight extent also from heat when the flesh is being cooked. There may be from one to three trichinæ in a cyst; frequently 25 per cent. of these parasites are thus encysted in the diaphragm, and therefore, when possible, a piece of this muscle should be procured; the back muscles on the other hand are the least attacked.

Either a section may be made of the muscle or it may be teased out with needles, and preferably, in the case of a long muscle, a point near its insertion should be selected—since this is a favourite site for encystment. The affected muscle is seen to be pale and œdematous, and if the worms are encapsuled, small rounded (or more truly, lemon-shaped), whitish specks, averaging about the size of a very small pin's head, are visible to the naked eye—and distinctly so by means of a hand-lens. A low power of the microscope, however, should be employed in every case, and the most characteristic appearance will be got by making a thin longitudinal

section of the affected muscle, and laying this in liquor potassæ of medium strength—which serves to make the muscle fibres transparent, and leaves the worm exposed in its coiled condition within the capsule. The soaking should not be prolonged beyond a minute or two, or the worm itself will also be cleared up. Glycerine is a good mounting medium, when a permanent specimen is desired. Sometimes, owing to considerable calcareous deposit in and around the walls of the capsule, a view of the worm is obscured; in these cases a drop of dilute hydrochloric acid, run under the cover-glass, will dissolve this up; or if, as is sometimes the case, an oil globule, or several, partially obscure the worm, a drop of ether applied in a similar manner to the acid will clear away the fat.

The parts which are most likely to be affected will easily be remembered if it be borne in mind that the worms migrate to their settlements from the gastro-intestinal tract, and chiefly from the stomach and the commencement of the small intestine. The diaphragm, the liver, the intercostal and abdominal muscles, are necessarily the first encountered, and therefore suffer most; but in later stages of the infection there is rarely a muscle which may not be affected. It is also a common practice to make an effort to diagnose the presence of the parasites in the living animals by examining the eyes and the under surface of the tongue, both of which will frequently show the small pin-head nodules.

The dangerous and often fatal condition created by these worms as they traverse the gastro-intestinal walls and travel to their encystment in the various organs of the body, is termed "Trichiniasis," a disease most prevalent in those countries where the uncooked—or im-

perfectly cooked—flesh of the pig is consumed, as in the form of sausages, &c. The symptoms of the disease resemble those of what a hybrid of acute rheumatism, enteric fever, and pyæmia may be imagined as producing.

Hot smoking, and efficient cooking, destroys these parasites; but in the latter case the meat must be "done through," *i.e.*, thoroughly cooked through the centre—or the parasites in this part of the joint, especially when shielded by calcareous walls, may escape the temperature necessary to destroy them, *i.e.*, that of 150° to 160° F.

There are small, semi-transparent, bodies called

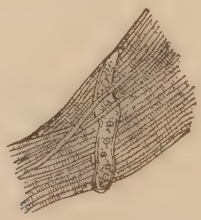


Fig. 83.—One of Rainey's Capsules. (× 285).

"Psorospermia" or "Rainey's Capsules," which somewhat closely resemble trichinæ, presenting as they do small oval or elliptical bodies, of similar sizes to encysted trichinæ. They are, however, made up of a thick membrane formed by small hair-like fibres arranged in lines, which encloses small oval—or rather kidney-shaped—granular cells closely adherent together, and the whole lies embedded in the muscle substance itself, *i.e.*, the sarcolemma. They are extremely common, and may exist in the flesh of most of the animals used for human consumption, and apparently when eaten they do not harm the human being.

Several more obscure bodies, the nature and significance of which we are still more in the dark about, may exist in flesh; such as bodies somewhat resembling pus cells, and others forming minute concretions or tiny hard nodules. Interesting as these are pathologically, they are rare, and when present, even in numbers, do not appear to affect the wholesomeness of the meat to any degree.

Actinomycosis. — The "ray-fungus" (actinomycosis), one of the "fission-fungi," is now becoming recognised as a parasite of commoner occurrence in the ox than was, until recently, suspected; the difficulties which stood in the way of an earlier appreciation of this fact, arose from the circumstance that both the ante- and post-mortem conditions of the disease so closely simulate those of tuberculosis.

It has not yet been proved that the disease can be communicated by the flesh of animals suffering from attack, and the vitality of the fungus, when exposed to heat, is very low. The subject is of such interest and importance, however, that a few additional facts are appended.

The parasite almost entirely affects the tongue, the jaws (especially the lower one), and the lungs, where they may be detected, by the naked eye, as small dirty white specks commonly about the size of a very small pea, but varying from the tiniest speck to $\frac{1}{4}$ inch in diameter. The parasites assume, when encysted, a peculiar symmetrical appearance, due to the fact that they consist of small linear elements, thicker at one extremity than at the other, and are so arranged that their smaller extremities are all placed towards a central point; the stellate or rayed appearance thus created is sometimes remarkably regular and uniform.

The tongue when affected is hard and swollen, and presents the flattened nodules chiefly upon its dorsal aspect.

Distoma hepaticum.—To examine for these parasitic trematodes the liver should be taken, and the bile ducts carefully exposed. They will be found as small organisms, in shape like little soles, and provided at their broad extremity with a sucker for attachment to the walls of the bile ducts. They average in size from 1 to 1½ inches in length, and about ½ inch in width.

Poultry and Fish.

The remarks hitherto made with regard to flesh are, of course, equally pertinent to poultry.

There are few points so easy to detect as commencing putridity in fish; this is fortunate, inasmuch as decomposition sets in rapidly, and appears to be more generally productive of poisonous symptoms than decomposing meat—the symptoms produced being very similar in both cases. The bright gills, the prominent eyes, the elastic resistance of the flesh, and the absence of any but the characteristic odour, all arise in evidence of freshness. The soft inelastic feel of the fish, and the unpleasant odour, furnish the chief clue—and the most reliable—of commencing decomposition, since some salesmen will revive the gills by artificial colouring agents, and keep the eyes prominent by a small piece of stick, fixed transversely in the head so that it presses the eye outwards on either side.

Iridescence—resembling the hues of a peacock's feather—is frequently seen upon the surface of the flesh of decomposing fish.

Fish are subject to parasitic attack, and notably is this the case with the cod, in which many varieties of these organisms have been found; cooking, however, effectually destroys them, and fortunately, in the case of fish, the flesh is not palatable unless the cooking is thorough.

The power of certain shell-fish to create at times, and with some persons, violent gastro-intestinal disturbance and nettle-rash—is well recognised, and mussels and oysters collected from near sewage outfalls, have had virulent poisonous properties ascribed to them.

Horse Flesh.

By the Horse Flesh Act, similar powers to those of the Public Health Act (1875) are given as to the inspection, examination and seizure of horse flesh sold for human food, and which is not legibly labelled "horse flesh." It becomes necessary, therefore, in order to check fraud, to be familiar with the chief differences which exist between the meat of the ox, &c., and that of the horse, and a comparison between them will serve an useful purpose here. In horse flesh the meat is darker and coarser—the muscular fasciculi being broader—than in ox-flesh; the odour of the fresh meat is different; and after the lapse of a day or two, as the flesh dries, it develops a peculiar faint odour, and imparts a soapy feel to the fingers. The fat is more yellow and soft, and possesses a sickly taste, and, in consequence, it is said that the fat is sometimes removed and replaced by ox-fat, which is skewered on to the meat. If the bones have not been removed they will afford an additional clue, inasmuch as they are larger and their

extremities (tuberosities, &c., for the attachment of muscles and ligaments) are larger and more marked—in addition to some anatomical differences in the construction of the horse's skeleton.

The tongue and the liver of the horse—together with some other organs—are also occasionally made to do duty for the corresponding organs in the ox. The tongue of the horse is, however, broad and rounded at its free end, instead of pointed as in the ox; and, if the hyoid bone is attached, it is found to be made up of 5 parts—whereas that of the ox consists of 9. The epiglottis is, moreover, smaller and more pointed in the horse. The liver, whether of the ox or sheep, consists of one very large lobe, and another relatively very small one; in the horse there are three large and distinct lobes, and a fourth which is very small.

Sausages, pork-pies, meat-pies, brawn, &c., have all given rise to symptoms of poisoning. The best works upon Hygiene will give the reader the outlines of those cases which have now become almost classical, such as Welbeck, Nottingham, Arlford, Retford and Chester, &c.; together with the steps and methods by which these articles were discovered to be the offending causes.

The nature of the agent which creates these poisonous symptoms is still very obscure. It seems to have the power, under some unknown conditions, of appearing and increasing in meat which is undoubtedly good and healthy at the time when it is employed in the making of sausages, pies, &c., for the fresh meat appears in no case to have caused any unpleasant symptoms. When, however, this meat is minced, cooked, and made up into sausages, &c., and kept for a little, the poisonous agent may make itself manifest. What then is its

nature? There are considerations which point to its being of a fatty character, but the most generally accepted theory is that it is of the nature of a crystallized toxic alkaloidal substance ("ptomaïne") or an albumose elaborated from the albuminous material by the agency of micro-organisms. All efforts to prove it to be any of the better understood poisonous bodies have failed, and it is apparently not of the nature of a fungus.

Bacilli have been found by Klein in some cases only.

In 1891, Dr. Ballard summarized the cases of food poisoning which had come under the notice of the Local Government Board since 1879. There were 14 such cases, of which 9 were from pig-meat, 1 each from veal and tinned salmon, and 3 in which the kind of meat was not stated. In almost every case the food had been prepared and kept in a raw state for at least a day prior to cooking, and was of a kind specially liable to be insufficiently cooked; it had been invariably stored for a while subsequent to cooking, and had only produced poisonous symptoms when eaten in the raw state. The incubation periods varied from 10 to 50 hours among those attacked. Probably the cause will be found as much in the miserable provisions now generally obtaining for meat storage, as in anything, and when one considers the damp, dark, unventilated conditions of larders generally, and their almost invariable proximity to the basement water closet, it is a matter for surprise that there are not many more such cases of food poisoning.

It is not a difficult matter to detect early decomposition in sausages, since the alteration in the smell alone will generally suffice; but if a little of the sausage is boiled with water, and some freshly prepared lime water is added, good meat yields only a faint am-

moniacal smell, whereas bad will give off a peculiarly offensive ammoniacal odour.

The skins of sausages have been known to contain mineral poisons, but this is very rare.

Eggs.

The composition of hen's eggs is roughly as follows:—

Shell, 10 per cent.

Albumen and fat, 23 per cent.

Water, 67 per cent.

The best tests for stale and bad eggs are the following:—

1. Fresh eggs are most transparent towards their centres if held vertically against the light; stale eggs are transparent at their upper extremities.

2. If two ounces of salt are dissolved in a pint of water, fresh eggs when placed in the solution sink, and stale ones float.

Toxic albumoses have been separated from decomposing eggs.

CHAPTER IX.

Alcohol, Vinegar, Mustard, Pepper, Sugar.

Alcohol.

The first question, which naturally arises with respect to these articles, is as to the amount of alcohol (C_2H_6O) which any sample may contain; the question, however, as to whether the amount of alcohol is that which the liquid was originally claimed to possess, and for which excise duty was paid, is a matter so entirely in the hands of the revenue authorities that the sanitary officer will not find himself in a position, if called upon, to decide it. It is extremely rare that a successful prosecution has been taken out under the Food and Drugs Act in connection with alcohol; nevertheless it is always open to us to ascertain whether different spirits reach the requirements (as regards alcohol) of the sale of Food and Drugs Amendment Act; and as certain drinks have entered the market which are sold as free from alcohol, it will be of advantage to see here how we should proceed to ascertain if this is a fact, in a simple and ready manner.

Some of the liquid containing alcohol, or suspected of doing so, is measured out—say 300 c.c., and then placed in a boiling flask or retort and boiled gently, until at least 200 c.c.* have distilled over into a flask fitted air-tight, by a cork, to the end of the condenser. This 200

* In the case of spirits it is better to distil *almost all* of the liquid over.

c.c. is next diluted to the original 300 c.c. with distilled water, and the specific gravity is taken in a specific gravity bottle, at the temperature of about 60° F. If it is 1000 the fluid is free from alcohol, and the amount of alcohol which has distilled over will be great in proportion to the extent to which this specific gravity falls below 1000—since, bulk for bulk, alcohol is lighter than water. Pure absolute alcohol at 60° F. has a specific gravity of 793. To find the percentage amount of alcohol, by volume, which corresponds to the specific gravity found, it is useful to consult the excellent alcohol tables of Mr. Hehner or Dr. Stevenson, in which these data are arranged side by side. If the percentage by volume of alcohol is multiplied by 0·8, the percentage by weight is obtained.

The expressions "over-proof," "proof," and "under-proof," have the following significance:—The term "proof" arose from a former mode of pouring the spirit over gunpowder, and setting fire to the vapour arising; if this fired the gunpowder, it was "over-proof," if it damped it so that the spirit burned without igniting the powder, it was "under-proof."

By "proof-spirit" is now implied a mixture of 56·8 per cent., by volume, of pure absolute alcohol in water, having a specific gravity of 920; and solutions weaker or stronger than this are "under" or "over-proof."

The sale of Foods and Drugs Amendment Act, 1879, fixes the following limits of the common "spirits," in addition to specifying the strength (given above) of "proof-spirit." Brandy, whisky and rum, may be 25 degrees "under-proof" (*i.e.*, may only contain 42·6 per cent., by volume, of absolute alcohol).

Gin may be 35 degrees "under-proof" (*i.e.*, may only contain 36·9 per cent., by volume, of absolute alcohol).

The percentage amounts of absolute alcohol generally present in spirits = 40 to 50 per cent. Wines = 7 to 17 per cent. Strong ales and porter = 6 to 8 per cent. Small beer = 1 per cent.

Beer.—The adulterants here employed are all detected by methods which will at once occur to the reader of the former pages of the book.

With regard to the "finings," which are added to clarify the beer or wine (and which are not regarded as constituting sophistication), their nature is very varying, and sometimes disgusting, and the detection of the composition of the "patent finings" commonly employed is a matter of the greatest difficulty, but isinglass and gelatine frequently enter into their composition.

Calcium and sodium salts, ferrous sulphate, sulphuric acid and alum, are the adulterants in the most general employ, and it will be convenient to proceed to detect the presence of those which would not thus be volatilised by collecting the ash and dissolving it, since the liquid itself is highly coloured. A solution of lead acetate will largely decolorise beer, and enable any *or all* of the above substances to be tested for.

It must be borne in mind that most of these, except when in excessive quantities, may be *normally* present, and are especially liable to gain access by the large amount of water employed in the brewing. The alkaline salts are added to correct undue acidity, and the few prosecutions which have taken place under the sale of Food and Drugs Act, have almost all been for an excess of common salt.

In a comparatively recent Revenue Act, a section is inserted which aims at the suppression of the adulteration of beer. It enacts that :—(1) A brewer of beer for

sale shall not adulterate beer, or add any matter or thing thereto (except finings for the purpose of clarification, or other matter or thing sanctioned by the Commissioners of Inland Revenue) before the same is delivered for consumption; and any beer found to be adulterated or mixed with any other matter or thing in the possession of a brewer of beer for the purpose of sale shall be forfeited, and the brewer shall incur a fine of fifty pounds. (2) A dealer in, or retailer of, beer shall not adulterate or dilute it, or add any matter or thing thereto (except "finings"); and any beer found to be adulterated or diluted or mixed with any other matter or thing (except "finings") in the possession of a dealer in or retailer of beer, shall be forfeited, and he shall incur a fine of fifty pounds.

Probably the most important consideration connected with beer is that of its acidity, since an abnormal amount of this denotes commencing changes of a deteriorating character, and implies what is perhaps the commonest adulteration, *i.e.*, sulphuric acid (employed to clarify, to lighten the colour, and to give the beer the hard taste which naturally only comes by age). The normal acidity of beer depends upon the presence of carbonic, acetic, lactic, malic, tannic or gallic acids, and it is obvious that such acidity can be estimated in terms of glacial acetic acid by exactly neutralising it by the standard alkaline solution already referred to (1 c.c. of which = 6 milligrammes of glacial acetic acid). If the total acidity exceeds 35 grains per pint when estimated thus, acid has almost invariably been added. It is most commonly somewhere about 20 grains.

Spirits.—"Fusel oil" (amylic alcohol) is the chief adulterant of spirit, and it appears to be, bulk for bulk, more injurious than ordinary (ethylic) alcohol.

Wine is much more adulterated than beer, and such adulteration is probably more generally and readily detected by the palate.

Here again the estimation of the acidity is of importance, but inasmuch as it varies considerably in the very numerous varieties of wines, the subject is a broad and somewhat indefinite one. In this case, however, results are more generally returned in terms of grains of *crystallized tartaric acid per ounce*, and the same standard alkaline solution which neutralises 6 milligrammes of glacial acetic acid will neutralise 7·5 milligrammes of crystallized tartaric acid.

If the acidity—which is chiefly due to such acids as

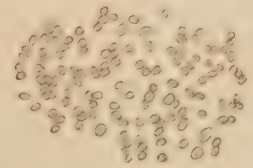


FIG. 84.—Torula Cerevisiæ (yeast plant) × about 200.

tartaric and malic (non-volatile) and acetic, formic and butyric (volatile)—exceeds 4 grains per ounce, it is undoubtedly injurious in a liquid of which considerable quantities are repeatedly drank.

A microscopic examination, as in the case of beer, will sometimes detect fungoid, &c., organisms.

The commoner adulterants are water, sugar, various ethers, lime salts, alum, lead and copper; and these are, of course, especially employed in the manufacture of the cheap clarets. Astringent agents—commonly tannin and catechu—are also used extensively.

Methods have already been given by which most of these can be detected:—The tannin in a measured

quantity of wine may be precipitated by adding a solution of gelatine and alum, and the precipitate then dried and weighed; 40 per cent. of this will consist of tannin.

The chief colouring agents are logwood, blackberry, elderberry and prune juices, sandalwood, cochineal and indigo, and these are so comparatively harmless, that in the face of the extreme difficulty of detecting them no attempt is necessary or advisable.

It may sometimes be necessary to examine any of these beverages for poisonous metals, in those cases where they are judged to have run the risk of such contamination.

Vinegar (Acetic Acid).

The most constant addition made to vinegar is that of sulphuric acid, and, since this addition is recognised by the legislature, it cannot be considered fraudulent. The sulphuric acid undoubtedly increases what harm—if any—attends the use of this dietetic condiment, since the acidity is thereby increased, and insoluble salts of lime have a greater tendency to form in the body.

The acidity of good vinegar should never fall below 3 per cent. when estimated as the stronger glacial acetic acid, and this fact, along with the specific gravity (which does not fall below 1015 in good vinegar) will serve to detect the addition of water. The amount of sulphuric acid can be estimated, as in water, by precipitating barium sulphate by the addition of a drop or two of hydrochloric acid and a solution of barium chloride. The precipitate is then filtered, washed, dried and weighed, and the weight multiplied by 0·34334 gives the weight of SO_3.

To estimate the total acidity of vinegar, take 10 c.c., dilute it with 90 c.c. of distilled water, and into 10 c.c. of this diluted vinegar (which will represent 1 c.c. of the undiluted liquid) run a solution of liquor sodæ which has been standardized with glacial acetic acid—so that a known amount of this acid is required to neutralise 1 c.c. of the alkaline solution. This solution is run into the dilute vinegar from a burette, and the amount required to effect neutrality can thus be calculated in terms of glacial acetic acid.

Example.—Supposing that 5 c.c. of the standard alkaline solution are required. But 1 c.c. neutralises 6 milligrammes of glacial acetic acid; ∴ 5 c.c. will neutralise 30.

∴ the acidity in 10 c.c. of dilute vinegar corresponds to 30 milligrammes of glacial acetic acid. But this 10 c.c. only contains 1 c.c. of the original undiluted vinegar; ∴ 1 c.c. (1000 milligrammes) of vinegar contains acidity amounting to 30 milligrammes of glacial acetic acid, or 3 per cent.

3 per cent. = 300 parts per 100,000; 300 × 0·7 = 210 grains per gallon; and 210 ÷ 8 = 26·25 grains to the pint.

In cases where vinegar has been added to "tinned articles," such as pickles, fish, &c., the liquid should be tested, where necessary, for lead, zinc, copper or tin, since the vinegar adds materially to the solvent action of the juices, &c., upon the vessels containing them. Copper can often be detected by allowing a piece of steel (as a knife blade) to lie in the liquid for a short time, when it becomes coated with a layer of copper.

The ash of vinegar is alkaline—if acid, some free mineral acid has unquestionably been added, and such

is probably the case even if the ash is neutral, the alkaline carbonates which largely constitute the ash being converted into neutral salts by sulphuric, &c., acids.

Mustard.

Little need be said upon this subject, for none of the adulterants employed have a harmful nature; such are:—turmeric, the different starches, linseed, and when much foreign material is added a little cayenne pepper is frequently mixed in with the mustard, in order to keep up its sharp flavour. All these are easily

Fig. 85.—The cuticle of the *white mustard seed* (× 200).

detected, and preferably by the microscope. The brownish-red reaction of turmeric when liquor potassæ is added, and the blue of starch in the presence of iodine, are both valuable and reliable chemical tests—the latter serving to detect the presence of materials containing starch, *i.e.*, the various "flours" and "meals," for pure mustard contains none of this substance. In several cases tried under the Food and Drugs Act, the justices have held that the addition of flour is permissible under the Act, as a preservative, for unmixed mustard does not keep well.

White mustard under the microscope presents certain well-marked characteristics. Foremost among these is

that presented by the outer coat or cuticle, which consists of a layer of large hexagonal, so-called "infundibuliform" cells, which present a central ostium occupied by other bodies—called mucilage cells; when water is added, these latter swell up, and escape from the mouth of the large hexagonal cells into the water, to which they appear to furnish mucilage.

Inside this layer are three less characteristic ones, the innermost consisting of a thin layer of large granular cells; and the interior of the seed comprises a fairly regular areolar network, containing granular matter and minute oil globules.

Black mustard is similar, but differs in the fact that the large hexagonal cells are absent.

Pepper.

Pepper is considerably adulterated, but mostly with agents which are harmless: linseed, various starches (wheat, rice, and pea flours chiefly), the palm nut powder, and some mineral substances (mainly sand or earthy matter).

The microscope, and the estimation of the ash, afford the best means of detecting sophistication. The added mineral matter, as in flour, can be mostly separated by shaking up thoroughly with chloroform. The mineral ash of pepper should not exceed 9 per cent. in a pure sample. The sand or earthy matter generally gains access in the following manner:—The berries are allowed to fall from the trees on to the ground, where many of their minute furrows become filled with the soil; or by the wearing of the stones between which they are ground the powder acquires some sand—3·27

per cent. is a reasonable margin to allow for the presence of this *unavoidable* sandy matter.

A rather rough but serviceable method, recommended by Neuss, and quoted in Parkes' "Practical Hygiene," consists in covering the pepper with concentrated hydrochloric acid, when, if the sample is pure pepper, it becomes of an intense and uniform yellow, and most of the foreign ingredients remaining uncoloured, readily betray their presence.

Unlike mustard, pepper contains starch.

Microscopical characters of pepper.—A transverse section of the *black pepper* berry shows the following notable points:—Starting from the cortex, most externally is

FIG. 86.—The cells forming the central part of the *pepper-berry* (× 100).

a layer two or three cells deep, arranged vertically, and very much resembling in appearance the bean-starch granules, *i.e.*, ovoid, with a central linear hilum crossed by transverse markings; next follows an ill-defined layer of elongated cells arranged transversely to the foregoing, and then a sort of irregular reticular tissue containing oil globules; more internally still, a well-defined single layer of large vertical more or less flask-shaped cells appears. The rest of the interior of the berry consists of flattened angular cells, dovetailed into each other, and containing starch.

White pepper is simply the central part of the berry.

Sugar.

The sugar of commerce is almost entirely cane sugar —very little glucose coming into ordinary domestic employ.

There is nothing under the head of adulteration of sufficient importance to concern us here, since what little is practised is of a harmless nature—with the exception, perhaps, of sand—which is sometimes added to the commoner sugars, and can be detected in the ash.

Fig. 87.—The sugar mite (Acarus Sacchari).

The amount of sugar present in any mixture is best estimated by Fehling's method, the rationale of which is:—If solutions of caustic potash and sulphate of copper be boiled together, the mixture becomes black—owing to the formation of the *black* oxide of copper; the presence of certain organic substances, however, and amongst them grape sugar, prevents the copper becoming so highly oxidised, and the *reddish-brown* sub-oxide of copper is in consequence formed. Cane sugar has no such action, but by boiling along with a drop or two of sulphuric acid it is readily converted into grape sugar ("invert sugar").

Fehling's solution is made by dissolving 34·639 grammes of pure cupric sulphate in water, and diluting to 500 c.c. The solution so obtained is mixed with another solution prepared by dissolving 173 grammes of the tartrate of potassium and soda in water, mixing this with 100 c.c. of liquor sodæ (sp. gr. 1·34), and diluting the mixture to 500 c.c.. When these two solutions, each of 500 c.c., are united, we obtain 1 litre of ordinary *Fehling's solution.* Of this solution 120 c.c. are now taken, mixed with 300 c.c. of strong ammonia (sp. gr. 0·880), and diluted up to a litre with distilled water. This constitutes **Pavy's standard solution,** and of it 20 c.c. corresponds to 0·01 gramme of *grape* sugar.

A known volume of this blue re-agent is placed in a white porcelain dish and brought to the boiling point, after which the solution containing sugar is added by a burette, until the blue colour has quite disappeared and is replaced by a brownish-red one—due to the suboxide of copper. The amount of sugar required to reduce a given quantity of the Fehling's solution being known, the estimation of the amount of sugar in the liquid under examination is easily arrived at. Moreover, the precipitate of the suboxide may be collected, washed, dried and weighed, and taken as a direct estimate of the quantity of sugar which has precipitated it.

CHAPTER X.

COFFEE—COCOA—CHOCOLATE.

THE unground coffee bean, as it reaches the market, consists of the true substance of the bean more or less enclosed in a thin skin—which is always most evident in the furrow.

Dr. Bell gives an analysis of Mocha coffee which serves to show the respective amounts of the constituents of the raw bean, and the changes in these amounts which are brought about by roasting.

	Raw Coffee.	Roasted Coffee.
Caffein*	1·08	0·82
Saccharine matter	9·55	0·43
Caffeic acids	8·46	4·74
Extracted by alcohol and containing nitrogenous and colouring matter	6·90	14·14
Fat and oil	12·60	13·59
Legumin or albumin	9·87	11·23
Dextrin	0·87	1·24
Cellulose and insoluble colouring matter	37·95	48·62
Ash	3·74	4·56
Moisture	8·98	0·63
	100·00	100·00

A hot water infusion of the ground coffee contains the oil, sugar, caffein, most of the mineral matters, dextrin, and some of the albuminous matters.

* The caffein of coffee and the thein of tea are apparently the same substance. Of the ash, the chief constituents are potash (over 50 per cent.), carbonic, and phosphoric acids; magnesia, lime, and sulphuric acid, are in smaller quantities.

Adulteration.—Chief among the adulterants is **chicory,** which is prepared from the root of wild endive. There are several well marked characteristics of chicory which serve to make detection of its presence an easy matter. To tabulate these:—

(1) It has a peculiar and distinct odour, different to that of coffee.

(2) In infusions of similar strength—made by placing similar amounts of chicory and coffee in the same quantities of water, bringing these up to the boiling point, keeping at this temperature for about half a minute, and then filtering—the infusion of chicory is much blacker than that of coffee, and its specific gravity is higher, *i.e.*, rarely below 1018, while that of coffee never exceeds 1010. The taking of the specific gravity is also a test for the presence of some of the other adulterants of coffee, *i.e.*, ground carrots, parsnips, turnips, and mangold-wurzel—the infusions of which will all show a specific gravity of 1015 and over: it is obvious, however, that these must be in considerable quantities along with the coffee to affect the specific gravity of the whole mixture very materially; it is also manifest that from the specific gravities the extent of the adulteration can be estimated, upon principles which have already been dealt with.

(3) Roasted chicory sinks in water *at once*, while roasted coffee floats for some time, and falls but slowly; and in chicory the sediment in the cup is soft and pulpy. Moreover, the particles of chicory become almost immediately enveloped in a light brown cloud, which, travelling up in streaks through the water, quickly imparts a distinct brown colour to the whole. Coffee will take a much longer time to achieve the same result, *i.e.*, from 15-20 minutes; and the other sweet

roots with which it is adulterated, *i.e.*, mangold wurzel, carrots, parsnips, &c., will require the lapse of several minutes.

(4) Microscopically, the characteristic cells and the dotted ducts of the chicory form a safe and rapid means of detection.

(5) Other tests have been suggested depending upon the difference in the amounts of ash and sugar in the two materials, but these involve unnecessary time and trouble.

The percentage admixture of chicory with coffee could be gauged by estimating the chlorine—which in pure coffee is only about 0·03 per cent., while in chicory it commonly amounts to as much as 0·25; it would be necessary, however, to incinerate the coffee, and it would be impossible to completely effect this without *some* loss by volatilization—which would be larger or smaller according to the precautions and care taken by the operator.

The sale of chicory is admissible, and its admixture with coffee is now generally taken for granted—indeed the majority will not drink the coffee without chicory; it only becomes an illegal and fraudulent adulteration when it is added to samples which are offered for sale as "pure;" such, however, have barely now a place upon the market, and certainly would not constitute 10 per cent. of all the samples taken—the admixture with chicory, &c., representing from 40 per cent. to over 90 per cent. in most samples. The substance is employed to blacken and thicken, and to give the slight bitter flavour so agreeable to "coffee;" but, owing to the absence of the alkaloid, it has none of the refreshing and stimulating powers of the latter; otherwise it has a very similar dietetic value—though, when mixed with

coffee, it decreases somewhat the percentage amount of all the constituents of that substance except the sugar, which it materially increases.

Chicory, in its turn, does not escape adulteration—the various starches, roots, burnt sugar, &c., used in connection with coffee, being also employed to adulterate its chief adulterant.

Roasted beans and other starches (potato, sago, &c.) are rarely employed, and when they are, a microscopic examination, together with the chemical test of iodine, will readily detect them. An infusion of *pure* chicory is not blued by iodine.

Hassall has recorded cases where mangold-wurzel, carrot, turnip, parsnip, &c., have been added in large quantities, but these must be very rare now, and the cells would all give the iodine reaction owing to the starch they contain. The starch grains of these roots somewhat resemble the cells of chicory under the microscope, and have little that is very characteristic about them. Even cabbage stalks and dandelion roots have been credited with affording means of adulteration.

Burnt sugar, or caramel, has been added to improve the colour aroma and taste of the infusion; it can be detected by the fact that it will rapidly colour water; the shining particles of caramel stand out from the comparatively dull particles of the ground berry, and if the former are picked out with forceps, they will be found quite soluble; they colour the water deeply and immediately, and the solution will reduce the copper-test solution, for much of the sugar employed is glucose.

It is rarely, if ever, necessary to get the mineral ash of a coffee sample, since mineral adulterants are almost unknown. If this is done, a reddish-brown colour of the ash would indicate the addition of the oxide of iron

—a very rare colouring adulterant!—and it would be then necessary to proceed upon the principles for the qualitative and quantitative estimations of this metal which have been already given. A deduction would have to be made in each instance for the small quantity of iron normally present—*i.e.*, from about 0·5 to 0·75 per cent. of the total ash.

Cocoa.

Cocoa nibs, on analysis, are found to mainly consist of the following ingredients, together with small amounts of others less defined :—

Fat—generally amounting to from 45 to 51 per cent.

Albuminous matter—commonly varying from 13 to 16 per cent.

An astringent substance resembling tannin.

Cellulose, starch, gum, cocoa-red (a substance of a resinous character, which furnishes the colour of cocoa).

An alkaloid—"theobromine," which closely resembles the alkaloids of tea (thein), and coffee (caffein)—about 1 per cent.

Mineral ash (3·5 per cent.); and water.

The ash mainly consists of potassium phosphate, and to a less extent of magnesia and lime salts; and as much as about a half of it is soluble in cold water.

With regard to fraudulent addition, the term has to be qualified with reference to cocoa very much as it is in the case of coffee. "Prepared cocoa" is mixed with starches (generally arrowroot or sago, sometimes potato), and these by serving to disguise the large amount of fat, which otherwise disagrees with some persons, renders it more generally preferred. Excep-

tion cannot, therefore, be taken to such addition, except in those cases where the sample is labelled "Pure Cocoa."

Some of the fat, however, can be readily removed, and this plan is by far the preferable one, as the added starch does not, while it reduces the percentage of fat, provide a substance of equal nutritive value to the other constituents of the cocoa which it displaces. The microscope will at once detect the addition of such foreign starches by disclosing their characteristic granules.

The oxide of iron, brickdust, chicory and chalk are now very rarely, if ever, added, although they are often mentioned as adulterants. The oxide of iron will give evidence of its presence in the red colour of the ash and by its chemical reactions, chicory by the microscope, &c., and chalk by effervescing with hydrochloric acid.

Sugar is generally added to prepared cocoas, and this may be estimated by Fehling's method.

The amount of fat, and of the ash which can be obtained from a cold water extract of the cocoa, furnish two tests of its purity. It is rarely necessary to employ them, however, and in the case of the ash this varies considerably in even pure samples. Practically the main test which is now applied to cocoa is that of the microscope.

Chocolate is cocoa from which much of the fat has been removed; the paste remaining is then mixed up with a considerable quantity of sugar and flavouring substances.

Microscopical Characters.—The microscopical characters of the raw *coffee* berry are distinctive. The testa or skin—portions of which are always ground up

with the rest—consists of long spindle cells with tapering rounded extremities, which are dovetailed into each other. Their characters, by the $\frac{1}{4}$ inch power, are well shown in the accompanying figure. The internal

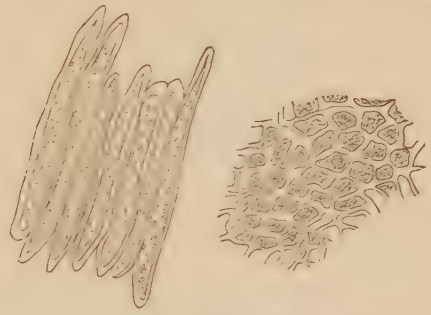


FIG. 88.—Coffee.
Cells of testa and cellular structure × about 200.

substance of the berry is made up of a thick areolar tissue, the meshes of which are very irregular in size and shape, and contain, in addition to starch, yellow angular masses and one or more rather large oil

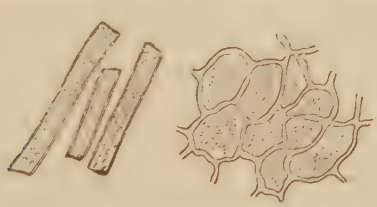


FIG. 89.—Chicory.
Dotted ducts and cellular structure × about 200.

globules; the walls of this meshwork are somewhat beaded in appearance.

In *chicory*, the cellular tissue, the large dotted ducts, and the lactiferous vessels are characteristic.

The cellular tissue consists of an oval or rounded meshwork, and is coarser than that of coffee. The lactiferous tubes are long pale and narrow branching tubes, which are filled with a substance called "latex." The dotted ducts appear as jointed tubes marked with bars, and possessing square extremities.

No starch is contained in chicory.

Of the other vegetable adulterants of coffee, *mangold-wurzel* possesses a cellular tissue which has a tendency to consist of larger and more distinct elements; the dotted ducts have fewer joints, there are no lactiferous tubes, nor is there any starch.

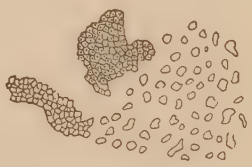


FIG. 90.—Cocoa Starch Cells × about 200.

Turnip closely resembles the former, but the presence of a considerable amount of woody tissue serves to distinguish it. It likewise contains no starch.

Carrots and parsnips contain starch, but no lactiferous tubes.

Microscopically the starch granules of *cocoa-nibs* are generally seen to be massed together in the cellular areolar tissue, which, under a high power, is seen to be hexagonal.

The most external layer of the husk of the cocoa bean consists of long flat quadrangular cells; but the bulk is made up of large distinct and rounded mucilage cells.

CHAPTER XI.

TEA.

THE leaves of the tea-plant (Thea sinensis), as they find their way into our markets, are generally mixed with some of the flower buds, together with numerous small stems of the plant.

An average sample of Black Tea shows about the following percentages of the two most important and characteristic constituents:—

Tannin, 15 per cent.

Thein, 2·5 per cent.

The ash is 6 per cent., and moisture commonly amounts to 10 per cent.

In the case of Green Tea, the thein and moisture appear to be generally less, and the tannin considerably more (*i.e.*, 27 per cent.).

Thein is the alkaloid of tea, to which it gives many of its most valued properties; the substance has been estimated as high as 6 per cent. in some samples.

The other constituents of the tea leaf are:—cellulose, vegetable albumen, extractives (by alcohol), chlorophyll and resin, pectin and pectic acid, dextrin or gum (Bell).

An infusion of the leaves will be found to contain the dextrin or gum, tannin, thein, most of the salts, and some of the albuminous substances, pectin, &c. A good judge of tea will form a ready and approximately accurate estimation of its purity and genuineness by the smell and taste of a fresh infusion.

The ash consists chiefly of potash—which amounts to

over 30 per cent. in most teas; but also of phosphoric acid, carbonic acid, lime, sulphuric acid, silica, alumina, iron, magnesia and soda.

It does not appear, at first sight, an easy matter for adulteration to be practised in this connection, and yet formerly there were probably few articles of commerce less systematically exposed to fraud. Fortunately this fraud—which is generally perpetrated before the leaves

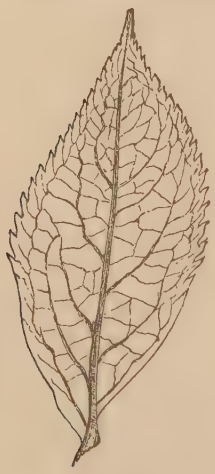


FIG. 91.
The elder-leaf (after Bell).

FIG. 92.
The willow leaf (after Bell).

reach this country—rarely takes a dangerous form hygienically, and has of late years very much diminished.

The commonest practice, at the present day, is the admixture with large quantities of either foreign leaves or of tea leaves which have been already infused. How can the former practice be best detected? The microscope affords the readiest and truest means! A very low power will suffice to disclose the structural charac-

ters of the various leaves, and fortunately the tea leaf possesses characteristics which mark it out from those of any other plant: the differences, however, are slight, and may be readily over-looked, especially when the leaves of the elder, willow, and sloe—which are those most commonly employed—are selected to serve the purposes of sophistication; there is much less difficulty in detecting the presence of beech and oak leaves, when these are added.

FIG. 93.
The sloe-leaf (after Bell).

FIG. 94.
The Tea-leaf (after Bell).

The common method of examination is to soak the leaves in warm water, to spread them out between glass slides, and then, by holding them up to the light, all the chief characters, including the venation, can commonly be discerned, and especially if a hand lens be employed; it is commonly necessary, however, to proceed to a low power of the microscope before a definite conclusion can be arrived at.

The characters of the tea leaf, when thus examined, are these :—the shape is elliptical, and though its length may be as much as five inches, it averages from about one to two inches in length, and in breadth from half to one ; the margin of the leaf shows distinct serrations, each of which is surmounted by a small spine, and these serrations do not quite extend to the point of attachment of the stalk ; the apex is slightly emarginate ; the primary veins come off somewhat dichrotomously from the midrib, and then branching off, form a markedly looped network extending to near the margin of the leaf, where, by bending back, they leave a narrow clear space.

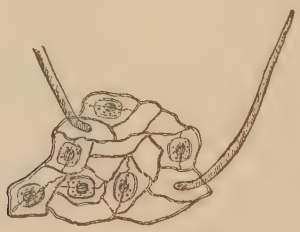


Fig. 95.—The epidermis of the under surface of the Tea-leaf. (× 285).

Under the microscope the leaf shows an epidermic layer of flattened cells possessing well marked sinuous outlines, coming off from a few of which are long slender unicellular hairs. On the under surface of the leaf there are a great number of oval stomates visible (fig. 95).

The most distinguishing characteristics of the tea leaf are :—the spine mounted serrations, which terminate a little before the point of attachment of the stalk ; the looped venation ; the notched apex ; the long slender unicellular hairs ; and the large number of stomata upon its under surface.

The leaves of the elder, willow, and sloe, are shown side by side on pages 388 and 389, in order that they may be more readily compared; the difference will be seen to be so slight that their early and extensive employment as adulterants almost goes without saying.

The leaf of the elder is seen to differ in the following respects:—its shape is ovate; the margin is sharply dentated, and the apex is pointed. The leaf is, moreover, seen to be asymmetrical—due to the fact that one lateral half of it is attached lower down the midrib than the other.

Microscopically, the epidermic layer of cells upon the upper surface of the leaf are less sinuous than in tea, and the cells present marked striæ. The unicellular hairs are either short thick and conical, or short with bulbous free extremities.

The leaf of the *willow* differs in the following respects:—it is elliptico-lanceolate in shape, with a pointed apex, and its contour presents shallow serrations.

Microscopically, the epidermic layer of cells is smaller, their contour is not sinuous, and the unicellular hairs are long and tortuous.

In the leaf of the *sloe* the shape is similar to that of the willow, and the margin is slightly more deeply serrated than that of the tea leaf.

Microscopically—of the epidermic layer the cells are smaller, their contour is not sinuous, and those on the upper surface of the leaf are striated. The unicellular hairs are shorter and thicker at the base than those of tea, and upon the under surface of the leaf the stomata are seen to be far smaller and fewer in number.

The question as to how the employment of used leaves may be detected is a much more difficult one to answer, for these are carefully prepared to resemble those which

are unexhausted. By working up and re-rolling the old leaves with sand and gum, and uniformly colouring or "facing"* them, in the case of green teas, with a mixture of Prussian blue turmeric and sulphate of lime, and in the case of black teas, with black lead—their appearance is made to closely resemble that of the unsophisticated article. The natural perfume is sometimes furnished, and apparently harmlessly so, by packing the leaves with certain aromatic flowers; and catechu may be added so as to strengthen the infusion. The sand or quartz serves the purpose of furnishing the stiffness of the natural unexhausted leaf, when dried; and the gum, while also aiding in this, imparts a gloss to the otherwise dull looking leaf.

The matter of detecting leaves which have been already used, is well nigh impossible to achieve when these are only added in reasonable quantity, for genuine samples of tea vary so much in their quality (*i.e.*, as to the relative amounts of their constituents), that leaves of some samples may even have been partially exhausted and yet yield more extract to boiling water than a very poor but genuine sample.

There is no practical utility, therefore, in introducing here any method of estimating the amount of that which can be extracted from tea by boiling water, since this varies within such very wide limits in pure samples.

Most will probably be learnt of this form of adulteration by the analysis of the ash of the leaves, and Dr. Bell found, that in average samples of genuine teas, this never reached 8 per cent.†—except in one sample out of a considerable number; and in only one case did the ash soluble in water fall below 3 per cent. It fol-

* The practice of facing is now little resorted to.

† The Society of Public Analysts have adopted this as the limit.

lows, of necessity, that a sample of tea containing much exhausted leaf, will show a reduction below the limit of the soluble ash; this should be estimated by taking a weighed quantity of tea (say 10 grammes), gently incinerating this in a platinum dish, and weighing the ash—which is generally grey in colour. The ash should then be treated with boiling water, and the whole filtered through a small Swedish filter paper; the insoluble part must next be thoroughly washed on the filter, re-ignited, and weighed—the difference between the weight obtained and that of the total ash will be due to the loss of soluble matter.* If the insoluble residue is treated with dilute hydrochloric acid, that which still remains insoluble will consist mostly of sand and quartz—which should not much exceed one per cent., or the sample is not pure.

The agents employed for colouring can be detected by well shaking up the leaves with cold water and decanting this immediately afterwards, so that no suspended matters shall have time to settle with the leaves. A slight sediment will form in the case of those leaves which have been "faced," and the nature of this is sometimes to be detected by the microscope—as in the case of indigo, when blue shining particles may be seen. Any colour due to Prussian blue is discharged by liquor potassæ and restored again by acid, and that due to indigo is discharged by the permanganate of potassium in the presence of liquor potassæ.

Copper and lead can be tested for by the ferrocyanide and chromate of potassium respectively, and turmeric, which is sometimes added to the indigo to furnish the green colour of green tea, is detected by its character-

* The Society of Public Analysts have adopted a limit of 30 per cent. as the smallest amount of "extract" in a genuine sample.

istic reddish-brown reaction in the presence of alkalies.

Ferruginous particles may sometimes be separable by means of a magnet, when they may be collected, dissolved, and analysed; and silica may be obtained and estimated from the ash.

The presence of catechu may be detected, except when it is in very small amount, by precipitating an infusion of tea leaves by a little solution of neutral lead acetate, then filtering, and treating the filtrate with a drop or two of a dilute solution of ferric chloride. A bright green colour appears, in the presence of catechu, which ultimately settles as a precipitate of a more sombre hue.

The tannin may be estimated from the infusion of a weighed quantity of tea, from which it may be precipitated by gelatine—40 per cent. of the precipitate, when collected and dried, will consist of tannin.

CHAPTER XII.

Preserved and Tinned Provisions—Colouring Agents employed in Food.

Most articles of food, when preserved in "tins," run some risk of contamination, and the source from which this danger issues is in either one of the following directions:—

(1) Chemical changes in the food itself—generally of decomposition, owing to preservative precautions being inefficiently taken.

(2) Substances added—as antiseptics—to preserve the contents.

(3) Substances employed as colouring agents.

(4) Impurities yielded by "tins," or the solder used in their manufacture. By the action of the juices upon the "tins," arsenic, antimony, lead, tin, or even zinc, may thus be taken up from the "tin" and solder. It is the vegetable, &c., acids naturally in the food, or those which are added to it, that act chiefly upon the "tins," and this action is increased by the galvanism which is sometimes set up between the metals present.

The most important consideration under the first heading, arises from the fact that in some preserved meats (bacon, sausages, minced beef, &c.) chemical products, under certain ill-understood conditions, are apt to form, and such foods give rise to symptoms of a choleraic type among those partaking of them.

Klein and others have discovered micro-organisms in some cases only, and the poison is generally con-

sidered to result from a chemical ferment produced by micro-organisms. Such ferments, then, are believed to be the products of putrefactive bacteria, and they furnish toxic albumoses and crystallised animal alkaloidal substances.

It seems that in those cases where poisoning has arisen from eating pork pies, that the temperature of cooking, though it may kill the putrefactive microbes, does not suffice to destroy their chemical ferments, which remain to give rise to symptoms of poisoning. And yet high venison and game, in which these same putrefactive agents with their products are present, are generally eaten with impunity! What is the explanation?

The present state of our knowledge with regard to these poisonous matters is so unsatisfactory and ill-defined that no acceptable solution to this question can be given. Any ordinary chemical analysis fails to detect a toxin, which can only be separated by special and difficult methods, and identified by its action upon living animals. The subject is a very complex one and its study is surrounded by many difficulties, but when one so frequently reads of poisoning by meat, milk, &c. —sometimes, alas, with a fatal result—and considers the many slight cases there must necessarily be where the food though the offending cause is not suspected of being so—the matter urgently calls for close investigation. Nothing could be much more unsatisfactory than the manner in which these interesting cases are commonly disposed of! What generally happens is the following:—A and B are poisoned—say by milk; an ordinary chemical analyst is called upon to examine this, and does so, of course, with negative results in the absence of the common well understood poisons; and there the matter ends! It is from the union of Bacteri-

ology and Chemistry that the whole truth will be ultimately arrived at, and probably neither the one science nor the other alone will suffice to detect the true origin and nature of these poisonous products.

The contents of the "tins" in preserved articles of diet are hermetically sealed down by solder at the boiling temperature, and the partial vacuum thus created in the tins is evidenced by their tops and bottoms being slightly depressed from the outside; should, however, there be any flaw in the "tins," or the solder seal be imperfectly applied, or should the heating process be but partially conducted, then the contents may go bad,—and in the latter case, owing to the accumulation of the gases of putrefaction, the tops and bottoms of the "tins" become quite flat, and later on, convex outwards. It is not difficult, therefore, in the majority of cases to detect, before opening them, those "tins" in which the contents are bad. Captain Stacpole (quoted by Mr. Walley in his "Practical Guide to Meat Inspection") says:—"If the meat has been improperly tinned, or if the slightest aperture exists in the tin or the solder, the contents will almost certainly be in a state of putrefaction, and as a result of this process gas will be disengaged, and this will give rise to a hollow or drum-like sound when the tin is struck with a solid body, in place of its being non-resonant. A hollow sound will also be produced if the tin has been imperfectly filled, but in this case the lid is generally depressed in the centre owing to the pressure of the atmosphere."

By raising the contents to the boiling temperature, and then hermetically sealing them, those micro-organisms which induce decomposition are destroyed, and their further access is guarded against; nothing is thereby added to the food article, and thus this process

along with such methods of preserving as freezing and sun-drying, are undoubtedly the safest and the best.

As a means to the same end, the employment of agents which will prevent the development of micro-organisms, and termed "antiseptics," is extensively practised. There seems no doubt that the use of these should be condemned, for although in the case of those more commonly employed their use has not been proved to cause any direct harm to consumers, it is rational to believe that such a salt as sodium salicylate may effect slight and indirect injury—which can none the less be disregarded because it is not immediately manifest—seeing that in larger amounts than any in which it is liable to be consumed with preserved foods, it has the power of working harm; moreover, few of these agents enter normally into the constitution of the human body, and at least they must be regarded as foreign bodies whose ingestion works no possible good, and which, not being foods, do not in any way make amends for the additional work of elimination which their presence demands.

The antiseptics most commonly employed are:—boracic acid, salicylate of soda, salicylic acid, salt and vinegar; but saltpetre, chloride of ammonium, the sulphates of potassium sodium and calcium, alum, creosote (which furnishes a smoky flavour), spirits of wine and sulphurous acid—have all been employed, but are becoming far less frequent. (For the characteristic reactions of boracic and salicylic acids *vide* "milk").

In order to preserve joints they have been coated with collodion, solid paraffin, and a mixture of gelatine and charcoal, and antiseptic agents have been injected by fine syringes into the flesh.

Of the impurities yielded by "tins," or by the solder used either in their manufacture or in their sealing, lead, copper, tin and arsenic are the only ones which concern us. The presence of tin has been very much overlooked, especially in this country, and many continental investigators have traced poisonous symptoms to its presence.

A tin sulphide is formed by the action of the albuminous matters upon the receptacles made of that metal, and it would be well to prohibit the employment of tin plate unless it be coated by some special preparation.

To a solution suspected of containing tin, after such has been evaporated to a considerably reduced bulk, a drop or two of hydrochloric acid should be added, followed by a few drops of a solution of sulphuretted hydrogen—when, if the metal be present, a yellow or blackish-grey precipitate is formed, according as to whether stannic or stannous salts are present. If to either of these precipitates an alkali (such as ammonia or liquor potassæ) be added, it is at once dissolved. The best corroborative test is the expensive one of adding gold chloride to the solution acidified by hydrochloric acid, and obtaining the beautiful and characteristic colour known as "the purple of Cassius."

The acidity necessary for the juices and liquors of "tinned" and potted articles in order that they shall take up these metals, is generally furnished by vinegar (acetic acid)—as in pickles, fish, &c.; and where this acid is employed there is always a special risk of metallic impurity being taken up, and hence these are the cases where the liquid contents should be most generally tested.

It is not necessary to repeat here the means of testing

for the various metals, since their characteristic reactions have been seen in treating of "water." The presence of copper, however, can often be roughly demonstrated by allowing a piece of steel, such as a knife-blade, to lie in the liquid for a short time, and noting the appearance of a bronze coloration upon it.

Having in view the fact that aluminium is now becoming cheaper, and that the metal is so extremely well adapted for making into "tins," pots, canteens, &c. (on account of its lightness, ductility and malleability), and owing to the fact that its bright appearance is very little affected by damp—the subject is growing into importance. The results of recent investigations do not yet appear to be conclusive on all points, but it may be accepted as proven that alcohol can dissolve up the metal in a slight degree, and that acids—even acetic and lactic—have a similar power though much more marked. It is probable, however, that even in the latter case there is not sufficient dissolved to give rise to symptoms of poisoning under the common conditions of food-potting—for the metal is not a very poisonous one.

The tin-foil around sweets, &c., sometimes furnishes lead to these articles.

The Colouring Agents employed in Confectioneries, Preserved Fruits and Vegetables, and as "Dyes," etc.

The only important matter in this connection, from a health standpoint, is to examine these various articles so as to ascertain whether the agents employed for colouring purposes are of a harmful nature or not.

It is comparatively rare, now-a-days, that harmful ingredients are added, but the health student must know what these *may* consist of, and be able at the same time to detect their presence. In order, therefore, that he may be alive to most of the sources from which any colour (harmful or otherwise) with which he may have to deal, has been derived, the following summary of the subject is given:—

1. **The harmful colouring agents** are for the most part of mineral origin; and the list which follows comprises all of those which are at all likely to be met with.

Lead has been employed for the production of yellow, red and white tints.

Arsenic for yellow, orange, magenta, violet-lake, and (in the form of Scheele's green, *i.e.*, the arsenite of copper, or Schweinfurth green, *i.e.*, the aceto-arsenite of copper) green.

Copper for green and blue.

Zinc for white.

Chromium for yellow and green.

Cobalt and manganese for pink and blue.

Mercury for vermilion-red.

Iron for various shades of brown, and in the form of Prussian blue, *i.e.*, the cyanide, for the beautiful blue of that name.

Gamboge and picric acid for yellow.

Gamboge is very insoluble in water but readily so in alcohol. Its presence is detected by dissolving out the colouring matter from the article by alcohol, and then, when water is added, the gamboge resin is precipitated; this precipitate will dissolve in ammonia, with the production of a blood-red colour.

Picric acid (tri-nitro-phenol) is detected by gently

heating after the addition of the cyanide of potassium, when the colour of the iso-purpurate of potassium forms.

Aniline colours are liable to contain arsenic, but if tested and found to be free from this metal they are harmless; as a rule only minute quantities of these are employed at a time.

2. The various **harmless colouring agents** are very numerous and are almost all of animal and vegetable origin. To enumerate those which are most commonly employed in the production of various tints:—

A red, pink, crimson and lake colour are generally produced by either *cochineal* or the "*aniline reds*."

The former colouring agent is derived from the cochineal insect, and is the more commonly employed. It can be detected by its character of turning violet with alkalies, and yellow with acids.

The reddish colours extracted from the root of the *madder*, from *beetroot*, and from *safflower*, are also used.

Logwood is also of common employ, and may be tested for by the addition of alum and ammonium carbonate—when a lavender or blue colour results (*vide* Bread).

A yellow, amber, or orange hue, is commonly imparted by *annatto*, *turmeric*, *saffron*, *aniline-orange*, or *chrysophanic acid* (which is extracted from rhubarb, and yields a fine purple colour with potash).

Annatto is very extensively used as a colouring agent, and like turmeric, it is readily soluble in alcohol, though not in water.

It is obtained from the seed of a plant named Bixa orellana, the starch grains of which, though smaller in size, closely resemble those of bean. While it is at the present day one of the most extensively employed

adulterants, it is itself subjected to considerable adulteration—turmeric and the flours of the various cereals being most frequently added, together with calcium sulphate and carbonate, Venetian red, &c. Copper is also sometimes added to prevent the growth of fungi. A microscopic examination, followed (in the case of the minerals) by a chemical analysis of the ash, will be required to detect the presence of these adulterants.

A violet or blue colour is frequently derived from the use of the *aniline* violets.

Indigo is extensively employed, and it sublimes in dense violet vapours when the article is burned.

The blue colour of *litmus* affords another means of such coloration. The substance is derived from Roccella tinctoria and from certain other lichens.

A purple colour is usually formed from a mixture of blue with some vegetable pink, such as rose-pink, logwood and cochineal.

The various *shades of brown* are most commonly imparted by heating *sugar* to various stages ("caramel"), and a *green colour* is now almost invariably obtained by the use of the *chlorophyll* extracted from plants rich in this substance, such as parsley, &c.

The *aniline* greens are also employed.

To decide, then, as to whether the colour employed is of a poisonous nature or not, the substance should be thoroughly macerated in a small quantity of slightly warmed distilled water, and if the colouring matter can be dissolved out by these means it is in all probability organic and harmless, providing the colour is not a yellow created by gamboge.

The colouring matter being thus dissolved out, is next treated with a solution of sodium hypochlorite and gently warmed, when corroborative evidence of its

organic origin is obtained if all the colour is discharged ("bleached").

If the colour is insoluble in water and not bleached by sodium hypochlorite, it is in all probability of a harmful nature, and of mineral origin, and the presence of copper, zinc, lead, chromium* and arsenic should at least be tested for. Such tests, in many cases, are best made from a solution of the ash of the substance, upon the principles of qualitative and quantitative analyses which have been already dealt with.

Of all articles, tinned vegetables have been most commonly found to be coloured (green) by copper. Some contend that the copper—as it is converted into an albuminate—is non-injurious, because insoluble; but Dr. Charteris and others seem to have established the fact that the albuminate of copper is rendered soluble by the process of digestion. It is highly desirable that it should be decided whether copper salts, as thus employed, *are* injurious to health or not, because there appears to be a strong inclination among magistrates generally, to take the view that they are *not* so; and accordingly summonses taken out against offenders are dismissed.

Much interest and discussion upon this subject has recently been evoked by an important case of supposed poisoning by this means, tried at Glasgow. Even expert opinion in this country still remains very conflicting as to the danger or innocuousness of the practice, as generally followed, *i.e.*, the peas are treated with a so-

* The most convenient test for chromium is to boil the solution with some carbonate of potassium, so as to create the chromate of potassium, and this in a neutral solution yields a purple precipitate with silver nitrate.

lution of cupric sulphate, this is almost immediately poured off, and the peas are subsequently well washed with water; they are next boiled in their tins and then soldered up. Probably the concensus of opinion tended to the direction of the innocuousness of the copper salt formed by the action of the copper on the peas (when this does not exceed 1½ grains per lb), either on account of its difficulty of solution, or from the very small quantities of copper in question. A writer in the "Chem. Zeit." attributes the coloration to the formation of a copper salt by an acid derived from phyllocyanin, which body is very inert, and insoluble in water, hydrochloric acid and acetic acid, though soluble in alcohol. The recent experiments of W. Ogilvie and M'Lean Wilson, which were prompted by the conflicting evidence in the case above mentioned, point very conclusively to the danger arising from the employment of the copper salt as a colouring agent. Both these investigators separated the colouring matter yielded by the copper to the peas, and the former by experiments upon mice and also his own body, showed that the organic salts of copper thus obtained were absorbed by the alimentary canal of man and mice, that they tend to accumulate in the liver, and are partially excreted in the urine, and probably to a less extent by the salivary glands. The latter experimenter found the copper compound to be soluble in distilled water, to which a drop of hydrochloric acid and a teaspoonful of Benger's liquor pepticus had been added, the whole being kept at a temperature of 98° F. for several hours. It thus seems that the old theory, that the copper formed with the legumen of of the peas a compound which is insoluble by the gastro-intestinal secretions, will have to be abandoned.

CHAPTER XIII.

Poisons in Foods—Arsenic in Wall Papers, &c.

One is sometimes called upon to examine an article of food for some poison, the nature of which may or may not be suspected; in the former case a direct examination may be made for the suspected poison, but in the latter all poisons must be sought after—both organic and inorganic; such an examination is more especially the province of the toxicologist, and presents a very wide field to survey; the commoner poisons, however, should be well understood by the Health Officer, and he should be able at any time to test for these, remembering in every case to retain one-third of the bulk of the substance under examination for any future contingencies that may arise.

It will frequently be found that the solution under examination is of a dark colour, or is somewhat of a slimy consistence, so that characteristic chemical reactions are unattainable; in these cases it is necessary to destroy the colouring and slimy matters before proceeding to test for metallic poisons, &c. This is effected in the following way:—Some of the solution is treated with hydrochloric acid, and then placed upon the water bath and heated for a short time. A solution of the chlorate of potassium is then gradually added, until there is no longer any smell of chlorine, when the whole is diluted with about an equal bulk of distilled water and filtered. The filtrate can then be examined for the presence of poisonous substances.

The mode of examining for arsenic and the commoner poisonous metals has been already seen, and it will only be necessary to introduce here, a means by which phosphorus and "prussic acid" (hydrocyanic acid) may each be detected.

Phosphorus.—It is necessary that this metal be found in the free state, for when it exists in the form of phosphates its presence proves nothing—for phosphates are the invariable constituents of animal and vegetable substances. The analysis must, moreover, be proceeded with without delay, or the phosphorus becomes oxidised to phosphoric acid.

The solution suspected of containing phosphorus is put into a flask, a cork is inserted (loosely) to the under surface of which a strip of filtering paper moistened with a neutral solution of argentic nitrate is attached, and the whole is heated to about 35°. In the presence of phosphorus the paper turns black, and if after some time no such change ensues, no unoxidised phosphorus is present.

If, however, there is a blackening, this may be caused by sulphuretted hydrogen, which may be tested for by a strip of paper moistened with a lead solution, and which may be absorbed by a concentrated solution of potash.

If negative results are obtained it will be advisable to test for *phosphorous acid*, produced by the partial oxidation of the metal, and some of the solution should be transferred to an appropriate apparatus in which hydrogen gas is generated, and careful notice taken as to whether the emerald-green coloration of the otherwise colourless hydrogen flame, reveals the presence of phosphorus. If the flame remains uncoloured, organic substances may be present and preventing the colour from appear-

ing; the apparatus should then be connected with an U-tube containing a solution of neutral nitrate of silver, through which the gas is allowed to pass for many hours in a slow stream; if phosphorous acid is present a precipitate containing the phosphide of silver will separate in the silver solution.

Hydrocyanic acid (HCN).—This poisonous substance should be *early* sought after in any food stuff, &c., since it is extremely volatile and unstable. The only other important poisonous cyanogen compound is the cyanide of potassium, for the ferro- and ferricyanides of potassium, and the cyanide of iron, are innocuous.

A great deal of stress is frequently laid upon the almond-like odour of these poisonous compounds, but such is not characteristic, for the odour of nitro-benzine and benzaldehyde closely resemble it.

If the article is not a liquid, a solution of it is made, and this is filtered through a moistened filter-paper; the filtrate is collected, acidified with hydrochloric acid, and then tested with the perchloride of iron for *ferrocyanides*, and with ferrous sulphate for *ferricyanides* and *soluble thiocyanates*. The presence of the cyanide of iron is disclosed by the Prussian blue colour of the solution.

Should these all be absent then *poisonous cyanogen compounds* may be tested for. If guaiacum paper treated with a two per cent. solution of copper sulphate is suspended in the air over the suspected solution placed in a bottle, and is found to become blued when the whole is gently warmed, this is a strong indication of their presence; but the solution if alkaline or neutral must be acidified by tartaric acid (Schönbein's test).

A corroborative test of great value is Scheele's iron test, in which an excess of liquor potassæ is added to the suspected solution; a mixture of a solution of a

ferric and ferrous salt is then added, and the whole acidulated with dilute hydrochloric acid; the colour of Prussian blue appears, in the presence of hydrocyanic acid.

If the *innocuous cyanides* are *present* it is necessary to proceed thus:—If the solution is acid it should be rendered neutral by the addition of pure liquor potassæ, and subsequently to this, a cold concentrated solution of sodium bicarbonate is added. The mixture is then distilled, and the distillate tested for hydrocyanic acid; and this distillation will exclude the presence of the harmless cyanides.

Arsenic.—There are a few special points which have to be here considered, with regard to the presence

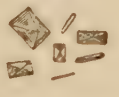


FIG. 96.—Crystals of Arsenic.

of this very poisonous metal in *food stuffs*—since a special line of procedure should be adopted in detecting its presence in these cases. The general practice is to stir the article up and mix it thoroughly with distilled water, and then place aside to settle; the almost clear supernatant liquid is then poured into a beaker; several of these washings are repeated, and ultimately all the water is drawn off as closely as possible.

Arsenious acid is only sparingly soluble in water, but the washings should be carefully examined—say by *Reinsch's test*; it is the residue which demands the closest investigation under the microscope. Sometimes small hard white grains of arsenious acid may be picked

out by means of a hand lens, and when these are placed in a glass tube and heated (after washing), a brilliant white sublimate forms, which when examined under the microscope is seen to consist of sparkling octahedrons and tetrahedrons; or again, small black scales of metallic arsenic may be seen, and when these are similarly treated, the well-known steel-grey arsenical mirror is formed upon the glass tube, beyond the flame.

Arsenic sometimes gains admission to food even in the process of cooking, from the enamelled, &c., cooking utensils employed.

The Examination of Wall Papers, Curtains, Dresses, Artificial Flowers, etc., for Arsenic.

This is sometimes of the greatest import. The dangers which may arise from the presence of this dreadfully poisonous agent, are too well appreciated, and have unhappily been too frequently demonstrated, to need any insistence upon here. There is a widespread impression among the general public that green is the only colour likely to contain this deadly agent; this has already been seen to be far from the truth, though there is no gainsaying that the metal has ben found more commonly present in this colour than in any other.

The writer has quite recently detected considerable traces of arsenic in a paper of a mauve colour, in a house where, strange to say, the inmates had previously had a green wall paper removed on account of its probable dangers, without having subjected it to an analysis. It is a difficult matter to enumerate the various colouring agents which may comprise arsenic in their constitution, and the matter may be dismissed by point-

ing out that almost every colour may do so; and it may be accepted that since the colour *green* is now so generally associated with arsenic in the popular mind, this is—of all others—the colour which is now most likely to be kept free from arsenic by manufacturers.

The metal gains access to the atmosphere chiefly in the form of arseniuretted hydrogen, in which form it is commonly disassociated from wall papers by the action of the paste—when this is kept more or less damp by walls which transmit moisture. Small grains of arsenious acid also sometimes enter the atmosphere in a suspended form, and rarely even metallic arsenic may thus be discovered; so that a microscopic examination of the dust of a room will sometimes disclose the presence of minute octahedral crystals and flakes.

The suspected article must be most thoroughly examined—much upon the principles shown upon a former page. If Scheele's green is suspected as furnishing the colour, a little of the paper or cloth may be thoroughly well soaked in liquor ammoniæ, when a blue colour is created. In no case, however, can the employment of either Reinsch's or Marsh's test be dispensed with.

If **Marsh's test** be employed—and it is an *extremely* delicate and reliable one—the paper or cloth, &c., is torn up into small pieces, and these are introduced into an apparatus of the following description:—a bottle is provided with a closely fitting doubly perforated cork; through one of these perforations is conducted a glass tube with an external trumpet-shaped mouth, and through the other a rectangular glass tube provided with a finely drawn point. So soon as the apparatus and reagents have themselves been found free from arsenic by a blank experiment, small pieces of the substance are placed inside the bottle, together with some

pure zinc, and the cork is inserted; through the vertical glass funnel some pure sulphuric acid is then run in, and as the result of an interchange between the acid and the zinc, hydrogen gas is liberated, and will escape at the small orifice in the finely drawn point of the rectangular glass tube—where it can be lighted. The hydrogen flame is a colourless one, but if any arsenic be present it unites with the hydrogen forming arseniuretted hydrogen, which burns with a characteristic bluish flame. If a piece of clean cold porcelain (white) be brought against this flame, the steel-grey metallic mirror of arsenic is deposited.

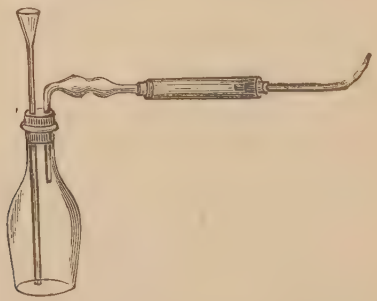


FIG. 97—Apparatus employed for Marsh's test.

Arsenic may exist in varying quantity in any material, *i.e.*, from a fraction of a grain (of arsenious acid) to even 80 grains per square yard—but since the smallest traces will condemn the article containing it, there is no necessity here to enter upon the subject of a quantitative analysis. It may be pointed out, however, that it is customary to estimate the metal as arsenious acid, ("white arsenic" = As_2O_3).

Supposing, for instance, a certain quantity of a green material yields 0·05 gramme of "Scheele's green," this arsenite of copper ($2\ CuO,HO,As_2O_3$) is found to have a

combined atomic weight of 375, of which arsenious acid (As_2O_3) forms 198; therefore $\frac{198}{375}$ of the 0·05 gramme of arsenite of copper = arsenious acid.

It is frequently useful to take advantage of the pattern upon a wall-paper, curtain, or carpet, &c.; and when this consists of flowers and leaves, &c., of different colours, to cut these out, arrange them according to their tints, and to examine each colour separately.

The presence of arsenic in the aniline dyes is often exemplified by the appearance of an arsenical rash upon the skin of those whose underclothing is coloured by means of these agents. More especially is this the case with the scarlet and blue stockings so frequently worn, and the legs in consequence are the commonest seats of such eruptions.

The presence of **lead** in these various articles may also induce chronic lead poisoning, and large quantities are commonly contained in wall paints and papers, in floor cloths, and in artificial flowers—and chiefly to create the colour red. An examination, therefore, for the presence of this metal sometimes also becomes necessary.

APPENDIX TO FOOD EXAMINATION.

The Sale of Food and Drugs Act, 1875.

(An Act to repeal the adulteration of Food Acts, and to make better provision for the sale of Food and Drugs in a pure state.)

Definitions.—The term "food" shall include every article used for food or drink by man, other than drugs or water.

NOTE.—Section 70 of the Public Health Act provides for the analysis of waters, including those used in the manufacture of drinks.

The term "drug" shall include medicine for internal or external use.

Description of Offences:—

SECTION III.—It is illegal—under a penalty which may amount to £50.

(*a*) To mix, colour, stain or powder, or

(*b*) To permit any other person to do so, or

(*c*) To sell when thus mixed—any ingredient with any article of food which renders the latter injurious to health.

SECTION IV.— The same applies to any *drug* when such measures effect injuriously the quality or potency of such drug, with the intent that the same may be sold in that state.

NOTE.—It is therefore not necessary in the case of *drugs* to prove injury to health.

SECTION V.—Provided that the offender was not ignorant of such admixture, &c., or could not with reasonable diligence have obtained that knowledge.

After the first conviction, 6 months imprisonment may be imposed.

NOTE.—Adulteration of food with *injurious* materials is now comparatively rare, and expert evidence is generally conflicting as to what materials *are* injurious, and hence proceedings are seldom instituted under this section.

NOTE.—A baker was fined at the Cambridge Petty Sessions for selling buns containing marked quantities of alum. In his defence he pleaded that the baking powders which he employed contained the alum, and that he was not aware of this fact. The magistrate held, however, that he should have ascertained the nature of the baking powders, and in default of this he could not have exercised reasonable diligence. (*Analyst*, vol. iv., p. 176).

SECTION VI.—A fine of £20 may be imposed for selling to the prejudice of the purchaser any article of food, or any drug not of the nature, substance and quality of the article demanded by the purchaser, save:—

(*a*) When the ingredient is not injurious to health, and has not been added fraudulently to increase the bulk or weight, or to conceal inferior quality.

(*b*) When the food or drug is a proprietary or patent medicine, and is supplied in the state required by the specification of such patent.

(*c*) Or is a compounded article.

(*d*) Or is unavoidably mixed with some extraneous matter in the process of collection or preparation.

NOTE.—This is the section under which almost the whole of the action under this act is taken, and is therefore by far the most important. A purchaser to be *prejudiced* must buy an article mixed with some foreign ingredient not specified at the time of sale, it is not sufficient that the article be of low quality so long as it is genuine.

SECTIONS VII. and VIII.—Compound foods or drugs must be sold with the ingredients in accordance with the demand of the purchaser, under a penalty not exceeding £20, unless:—

(*a*) The ingredient is not injurious to health.

(*b* Or intended to fraudulently increase the bulk or weight.

(*c*) Or to conceal the inferior quality of the article, *provided* a legible notice that the article is mixed be affixed.

NOTE.—This section applies to compound articles of food such as infant's foods, &c., and in the case of drugs, to "prescriptions." With regard to drugs, there is nothing specified in the Act which shall guide us as to the standard composition or quality of different drugs. The British Pharmacopœia is not accepted as a standard for such medicines which it includes, but if the medicine is ordered in exactly similar terms to those employed in the B. P., and the purchaser is supplied with an article not similarly compounded, he would be prejudiced by the purchase. A grocer was fined at Glasgow for selling "chemical food" said to contain 2½ gr. of phosphate of lime and 1 gr. of iron in every teaspoonful. Analysis discovered, however, only ⅓ gr. of phosphate of lime and ½ gr. of iron to the teaspoonful. (*Analyst*, vol. vi.).

SECTION IX.—A similar penalty may be imposed for selling without notice any article of food from which any part has been abstracted so as to affect injuriously its quality, substance or nature.

NOTE.—This section is especially designed to prevent the abstraction of cream from milk.

SECTION XIII.—Any medical officer of health, inspector of nuisances, inspector of weights and measures, inspector of a market, or any police constable, under the direction and cost of the local authority, may purchase and procure any sample for analysis.

SECTION XVII.—A penalty of £10 may be imposed for refusal to sell any article or drug exposed for sale, on tender of a reasonable

price for same. (N.B.—There must be an actual *tender* of the money, apart from any proposal of purchase).

Section X.—Various specified local bodies may, and shall when required by the Local Government Board, appoint analysts, and such appointments, and any dismissals, shall be subject to the approval of the Local Government Board. But no such analyst must be engaged even indirectly in any trade or business connected with the sale of foods or drugs in the place for which he is appointed.

Section XIX.—Analysts appointed must send in a quarterly report to the local authority, who shall transmit annually to the Local Government Board a certified copy of such reports.

Section XXI.—The analyst's certificate is evidence, but he must attend personally if required to do so; and the justices may send sample to Somerset House for analysis at their discretion.

Section XII.—All purchasers of foods and drugs are entitled, on payment of a fee not exceeding 10*s*. 6*d*., to have an analysis made, and a certificate of the result given them.

Section XVI.—Articles may be forwarded to the analyst through the Post Office in a registered letter.

Section XIV.—The purchaser must, after the purchase is completed, notify his intention of having the article analysed by the public analyst, and offer to divide it into three parts, each to be marked and sealed or fastened, and one of these he shall deliver to the seller or his agent, another he shall retain for future comparison, and a third shall be given or sent to the analyst.

Note.—To show how necessary it is to carry out this section according to the exact words employed in its construction, the following cases will suffice:—A grocer convicted of selling adulterated coffee appealed successfully to the Durham Quarter Sessions on the ground that the purchaser had merely said that he was going to have the sample analysed and *did not add* "by the public analyst." (*Analyst*, vol. ix., p. 28). A summons was dismissed at Portsmouth because although the purchaser had divided the sample into three parts, he had not made *an offer* to the vendor so to do.

Section XV.—If the seller will not accept a part, the analyst shall divide the sample into two, one of which parts he shall seal or fasten up and deliver to the purchasers, who shall retain the same for production in case proceedings are taken in the matter.

Section XX.—If by the analysis an offence against the Act appears to have been committed, the person causing the analysis to be

made may proceed in a summary manner to recover the penalty imposed before any justice in petty sessions assembled having jurisdiction in the place where the article was purchased, and any penalty may be reduced according to the judgment of the justices.

SECTION XXIII.—Provision is made for the defendant to appeal (in England to the next General or Quarter Sessions of the Peace) under certain conditions.

SECTION XXV.—If the defendant proves that he purchased the article as the same in nature, substance and quality, as that demanded of him by the prosecutor, and with a written warranty to that effect; that he had no reason to believe at the time of selling it that the article was otherwise; and that he sold it in the same state as when he purchased it,—he shall be discharged from the prosecution, but shall be liable to pay the costs incurred by the prosecutor, unless he shall have given due notice to him that he will rely on the above defence.

SECTION XXVI.—Penalties in England go to the authority and are to be applied to the expenses of the Act.

SECTION XXVII.—Heavy penalties are imposed upon persons forging certificates or giving false warranty respecting an article of food or drug, or for affixing false labels.

SECTION XXX.—All tea imported as merchandise shall be examined by persons appointed by the Commissioners of Customs for the inspection and analysis thereof—such persons may take samples and give them to the analyst appointed, and if mixed with other substances or "exhausted" the tea shall not be delivered except by the sanction of said Commissioners, who may impose certain conditions, or even destroy the tea if found to be unfit for human food. ("Exhausted" includes any tea deprived of its proper quality and strength by steeping, infusion, decoction or other means).

THE SALE OF FOOD AND DRUGS AMENDMENT ACT, 1879.

SECTION II.—It is no defence of the sale of adulterated articles to allege that the purchaser, having bought only for analysis, was not prejudiced by such sale, or that the article though defective in nature, or substance, or quality, was not defective in all three respects.

Sections III and IV.—A sample of milk may be procured at the place of delivery as well as in the shop, &c., and a penalty of £10 may be enforced for refusal to give such sample.

Section V.—What applies to premises, shops, &c., in the previous Act applies equally to articles sold in any street or open place of public resort.

Note.—In order to act in strict conformity with the requirements of the Act, the purchasers should demand a sample (of milk), and offer the price of it, not while the milk is being carried along the streets but when the vendor stops at any premises to deliver it.

Section VI.—It shall be a good defence to prove that with regard to spirits not adulterated, save by water, that such spirit is not reduced to more than 25 degrees under proof in the case of brandy whisky or rum, or 35 degrees under proof in the case of gin.

Section X.—In all prosecutions under the previous Act, the summons to appear before the magistrates shall be served within a reasonable time, and in the case of a perishable article—not exceeding 28 days from the time of the purchase; and particulars of the offence or offences against the said Act of which the seller is accused, and also the name of the prosecutor, shall be stated on the summons; and the summons shall not be made returnable in a less time than seven days from the day it is served upon the person summoned.

Form of Certificate of Public Analyst.

To

I, the undersigned, public analyst for the do hereby certify that I received on the day of 18 from a sample of for analysis (which then weighed), and have analysed the same, and declare the result of my analysis to be as follows:—

I am of opinion that the same is a sample of genuine

or

I am of opinion that the said sample contained the parts as under, or the percentages of foreign ingredients as under.

OBSERVATIONS.*

As witness my hand this day of
at

In *transmitting articles to Somerset House for analysis* the following regulations should be observed:—

1. The sample should be carefully secured in paper or in a box and sealed, and the seal should be stamped in a way which would enable its identity to be sworn to.

2. The sample should be addressed thus:—"The Commissioners of Inland Revenue Office, Somerset House, London, W.C. (To the Principal of the Laboratory)"; and the place from whence the sample is sent, and the nature of its contents, should be written upon the packet.

3. At the same time a letter should be sent to the Principal of the laboratory, informing him of the dispatch of the sample, and the reasons for desiring an analysis, together with the nature of any suspected adulteration (if known).

THE MARGARINE ACT, 1887.

(An Act to protect the public against the sale, as butter, of substances made in imitation thereof, as well as of butter mixed with any such substances).

The word "butter" shall mean the substances usually known as butter, and made exclusively from milk or cream or both, with or without salt or other preservatives, and with or without the addition of colouring matter.

* Here the analyst may insert, at his discretion, his opinion as to whether the mixture (if any) was for the purpose of rendering the article portable or palatable, or of preserving it, or of improving the appearance, or was unavoidable; and may state whether it is in excess of what is ordinary or otherwise, and whether the ingredients or materials mixed are, or are not, injurious to health.

In the case of a certificate regarding milk, butter, or any article liable to decomposition, the analyst shall specially report whether any change had taken place in the constitution of the article that would interfere with the analysis.

The word "margarine" shall mean all substances, whether compounds or otherwise, prepared in imitation of butter, and whether mixed with butter or not; and no such substances shall be lawfully sold except under the name of "margarine," and under the conditions set forth in this Act.

NOTE.—Margarine—this term will include "butterine" and "oleomargarine."

Heavy pecuniary penalties may be inflicted, upon conviction, for offending against the Act.

Every package whether open or closed, and containing margarine, shall be branded or durably marked "margarine" upon the top bottom and sides, in printed capital letters not less than $\frac{3}{4}$ inch square; and if such is exposed for retail sale there shall be attached—so that it is clearly visible to the purchaser—a label marked, in printed capital letters not less than $1\frac{1}{2}$ inches square, with the word "margarine."

Every person selling any quantity of margarine, save in a package duly branded or duly marked as aforesaid, shall deliver to purchaser the same in a paper wrapper, on which shall be printed in capital letters not less than $\frac{1}{4}$ inch square, the word "margarine." A person becomes liable under the Act, by dealing with, selling, exposing or offering for sale, or having in possession for purpose of sale, any quantity of margarine contrary to the Act, unless he shows to the satisfaction of the Court that he purchased the article as butter, and with a written warranty of opinion of invoice to that effect, and that he sold it in the same state as when he purchased it.

Anyone authorised under section 13 of the Sale of Food and Drugs Act may procure samples for analysis from any package *without purchase*, but otherwise in accordance with the provisions of the Sale of Food and Drugs Act.

Every manufactory of margarine must be registered.

THE SALE OF HORSE-FLESH &C., REGULATION ACT, 1889.

(*An Act to regulate the sale of Horse-flesh for Human food*).

SECTION I.—No person shall sell, offer, expose, or keep for sale, any horse-flesh for human food, elsewhere than in a shop, stall, or place over or upon which there shall be at all times painted, posted,

or placed in legible characters of not less than four inches in length, and in a conspicuous position, and so as to be visible throughout the whole time (whether by night or day) during which such horse-flesh is being offered or exposed for sale—words indicating that horse-flesh is sold there.

SECTION II.—Horse-flesh must not be sold as other meat than horse-flesh.

SECTION III.—Any medical officer of health, or inspector of nuisances, or other officer of a local authority acting on the instructions of such authority, or appointed by such authority for the purposes of this Act, may at all reasonable times inspect and examine any meat which he has reason to believe to be horse-flesh, which is exposed or deposited for the purpose of sale, or of preparation for sale, and intended for human food, in any place other than such shop, stall, or place as aforesaid; and if such meat appears to him to be horse-flesh, he may seize and carry away, or cause to be seized and carried away, the same, in order to have it dealt with by a justice, as hereinafter provided.

SECTION IV.—On complaint made on oath by a medical officer of health or inspector of health, or other officer of a local authority, any justice may grant a warrant to any such officer to enter any building or part of a building other than such shop, stall, or place as aforesaid, in which such officer has any reason for believing that there is kept or concealed any horse-flesh which is intended for sale, or for preparation for sale for human food, contrary to the provisions of this Act; and to search for, seize, and carry away, or cause to be seized and carried away, any meat that appears to such officer to be such horse-flesh, in order to have the same dealt with by a justice, as hereinafter provided.

Any person who shall obstruct any such officer in the performance of his duty under this Act, shall be deemed to have committed an offence under this Act.

SECTION V.—If it appears to any justice that any meat seized under the foregoing provisions of this Act is such horse-flesh as aforesaid, he may make such order with regard to the disposal thereof as he may think desirable; and the person in whose possession or on whose premises the meat was found, shall be deemed to have committed an offence under this Act, unless he proves that such meat was not intended for human food contrary to the provisions of this Act.

SECTION VI.—Any person offending against any of the provisions of this Act, for every such offence shall be liable to a penalty not exceeding £20, to be recovered in a summary manner.

SECTION VII.—For the purpose of this Act, "horse-flesh" shall include the flesh of asses and mules, and shall mean horse-flesh, cooked or uncooked, alone, or accompanied by, or mixed with, any other substance.

SECTION VIII.—For the purposes of this Act the local authorities shall be:—In the city of London and liberties thereof, the Commissioners of Sewers, and in the other parts of the county of London the vestries and district boards acting in the execution of the Metropolis Local Management Acts, and in other parts of England the urban and rural sanitary authorities, and in Ireland the urban and rural sanitary authorities under the Public Health (Ireland) Act, 1878.

SECTION IX.—In the application of this Act to Scotland, the expression "justice" shall include sheriff and sheriff substitute, and the expression "local authority" shall mean any local authority authorised to appoint a public analyst under the Sale of Food and Drugs Act, 1875, and the procedure for the enforcement of this Act shall be in the manner provided in the 33rd section of the said Sale of Food and Drugs Act, 1875.

AERATED WATERS.

The examination of aerated waters should be conducted on precisely the same lines as those of an ordinary water sample—that is to say, an effort must be made to ascertain the freedom of the water from dangerous organic and metallic contamination.

All such "waters" consist of ordinary water into which carbonic acid gas is forced under pressure:—Lithia water is, in addition, charged with lithia; potass water with bicarbonate of potassium; soda-water is commonly sold without the addition of any soda, but when such is added, it is usually to the extent of 10 grains (of bicarbonate) to the pint; seltzer-water is

naturally aerated, and is found at Nieder-Seltzers, Germany—it contains, in addition to its free carbonic acid, sodium chloride and calcium carbonate.

Lemonade and ginger-beer are especially liable to contain traces of lead.

Drugs.

The object of an analysis of drugs is to detect impurity or adulteration, and the lines upon which one proceeds are those of a qualitative and quantitative chemical analysis—aided, in a few cases, by the microscope. It will be of service to bear in mind that in many cases it is convenient and expeditious to proceed by methods of alkalimetry and acidimetry. To briefly indicate the method of procedure, take for instance a seidlitz powder (pulvis sodæ tartaratæ effervescens, B.P.); the powder contained in the blue packet should consist of tartarated soda, in dry powder, 7·776 grammes, and bicarbonate of soda, in dry powder, 2·592 grammes; the whole should thus weigh 10·368 grammes. After ascertaining the presence of these two salts, and the absence of common salt or other likely form of adulteration, the powder should be dissolved in neutral distilled water; the solution will be a markedly alkaline one, and it may be learnt, from the amount of decinormal acid solution required to neutralise it, whether the bicarbonate of soda is in excess—as judged by considering whether the alkalinity of the whole exceeds that which should be present, in a mixture of the two salts containing only 2·592 grammes of bicarbonate. All excess of alkalinity invariably indicates—owing to its greater cheapness—an unduly large proportion of

the bicarbonate, the excess of which may be estimated from the excess of alkalinity it furnishes.

The white powder, which contains 2·4624 grammes of tartaric acid, in dry powder, need only be weighed and tested for purity. It should be completely soluble in water; when heated it should give off an odour of burnt sugar and leave a residue of carbon; warming with sulphuric acid should carbonize it uniformly in a minute or two; and on shaking with potassium acetate a white crystalline precipitate of potassium-hydrogen-tartrate should be produced.

PART VI.

METHODS EMPLOYED IN BACTERIOLOGICAL RESEARCH, WITH SPECIAL REFERENCE TO THE EXAMINATION OF AIR, WATER AND FOOD.

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CHAPTER I.

Sterilisation.

A rigid attention to detail and absolute cleanliness are essential to the investigation of any bacteriological problem.

Sterilisation, according to the end in view, is performed in several ways, viz., by the use of *antiseptics*, the direct action of *flame*, *hot air*, *boiling*, the action of *steam* or *superheated steam*, and by filtering through *porous earth*.

Antiseptics.—These are especially useful in *cleansing* any apparatus or utensils which may have been contaminated by micro-organisms. Thus a 1 in 1000 solution of perchloride of mercury should be used to wash regularly the tables, floors, &c., where bacteriological investigation is going on. In the same manner the hands should be well rinsed in the sublimate after handling the pathogenic organisms. Syringes and glass

work may also, after use, be steeped in perchloride. The skin of man or animals, when it is desired to take a sample of blood (for cover-slip preparations or cultivation), or to make an inoculation, should be well scrubbed with an antiseptic.

As sublimate, carbolic acid, and the other antiseptics are powerful bactericides, they must not be allowed to come in contact with the media or cultures. Thus syringes and glass after cleansing with the above solutions must be rinsed in water and rendered sterile by hot air or steam, previous to use. Occasionally a flask or other piece of apparatus is rinsed in alcohol, ether or chloroform, and the fluid allowed to evaporate. Filter paper, scraps of tissue, or blood, where contaminated with micro-organisms, and cultures, should be thrown into a vessel of sublimate or burnt. Where the tables are enamelled and the floors tiled, strong solutions of hydrochloric or sulphuric acid may be used with advantage. In the case of the floors sawdust moistened with a solution of sulphuric acid serves both as a bactericide and to allay the dust in sweeping.

Direct action of flame.—This simple method is made use of every day in the bacteriological laboratory, to sterilise the platinum needle employed in making cultures, &c. It is to be observed that the needle should be held vertically so that the portion of the glass rod to which the "needle" is fused is sterilised at the same time (see later). Pipettes, ampullæ and narrow glass tubing may be readily sterilised by passing quickly through the flame. It is unnecessary to point out that burning is the most efficacious means of getting rid of all refuse.

Hot air.—Hot air is a very useful method of sterilising glass, metal work and cotton-wool. The hot air

chamber is a simple and cheap form of iron oven (fig. 98). It is furnished with a thermometer and heated by a Bunsen. A temperature of 170° C. is perhaps the most serviceable heat for most purposes, and maintained for from ten to fifteen minutes effectually sterilises most apparatus.*

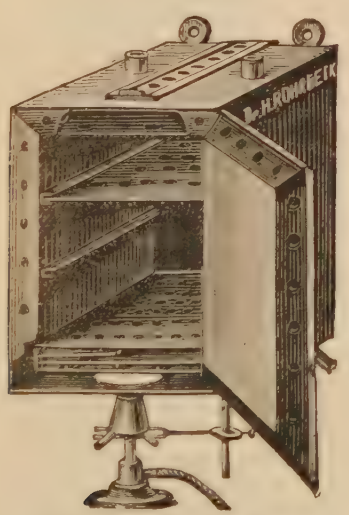

Fig. 98.—The hot air oven.

Boiling.—Boiling, or subjecting to steam for from ten minutes to half an hour, sterilises many things. There are very numerous forms of *steam sterilisers*. Figure 99 represents the well known steam steriliser of Koch.

* In sterilisation allowance must naturally be made for the thickness and conductivity of the object to be sterilised. The surgeon for instance is satisfied with boiling his instruments for ten minutes, but insists on several hours for the ligatures.

The principle of this apparatus is that of the ordinary kitchen steamer, and many of the American

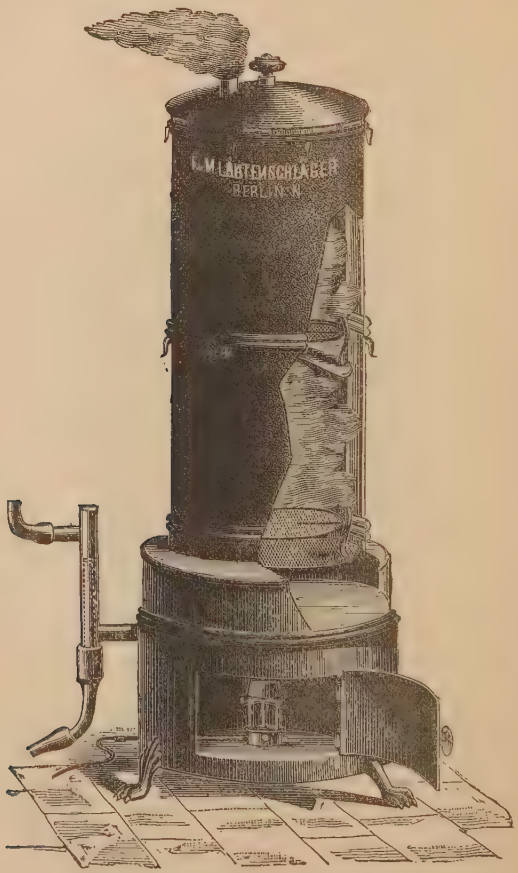

FIG. 99.—Steam steriliser of Koch.

vegetable steamers are more rapid and cheaper. It is filled to the right level with water, and the apparatus

to be sterilised is placed in the steamer; it is furnished with a thermometer. Sterilising in steam at 100° must be employed in the case of gelatine. Agar-agar will bear an exposure to 120 C. To make sure that the sterilisation is absolute in the case of the nutrient media (gelatine chiefly), successive sterilisation must be resorted to. Thus the gelatine should be kept at 100° C. for a quarter of an hour on three consecutive days. The reason for so doing is this:—Whilst the vegetative forms of the micro-organisms may be killed at one boiling, the spores need not; allowing an interval of a day, however, gives time for the spores to develop into adult forms, and these are killed by the reboiling. It may be pointed out that the *hay bacillus* is isolated from the other numerous organisms in an infusion of hay, by boiling the latter for half an hour; at the end of this time all the organisms are killed except the spores of the hay bacillus. Where steam is to be used for sterilising or in the manufacture of the nutrient media, we strongly recommend the use of the following apparatus:—

The Autoclave.—This is a form of Papin's digester. It is represented in figure 100, and consists of a boiler to which may be firmly fixed a lid furnished with a steam cock, safety valve and gauge; the latter indicates the steam pressure and the temperature corresponding to it, thus a pressure of one atmosphere of *steam* corresponds to a temperature of 120° C.

It is the most generally serviceable of all the sterilisers, both on account of the rapidity of its action, and from the fact that a short exposure in the super-heated steam serves to thoroughly sterilise.

In its use certain precautions must be adopted. Care must be taken that there is sufficient water in the

bottom reservoir, and that all the air is thoroughly driven out before the steam cock is shut off. If the latter precaution is not taken the gauge will record, in addition, the pressure of the expanded air; therefore to ensure that all the air is driven out, the steam should

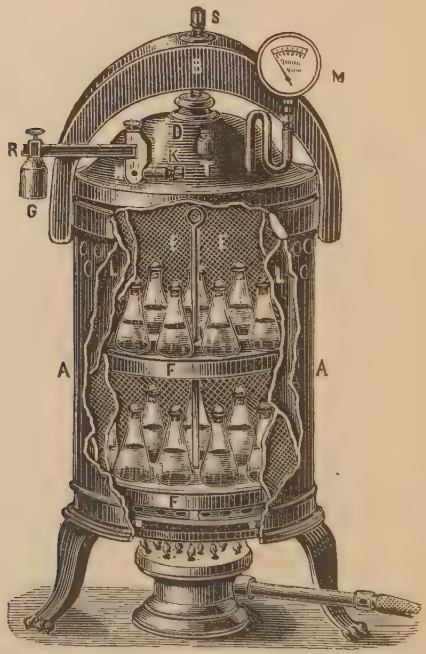

FIG. 100.—The autoclave, showing flasks in the interior undergoing sterilisation.

be allowed to issue through the stop cock for about five minutes. When the cock is closed, the guage must be closely watched, lest any accident should happen. The desired temperature having been reached, the gas must be lowered, in order to keep the temperature con-

stant. *The stop cock must not be opened till the pressure inside the boiler has regained the normal.*

For most purposes an exposure to a temperature of 115° C. for twenty minutes, or to 120° for ten to fifteen minutes, serves to sterilise. Gelatine, it is to be remembered, must not be superheated, so that the stop cock must be left open whilst making it. In the manufacture of agar, the autoclave is very useful, the high

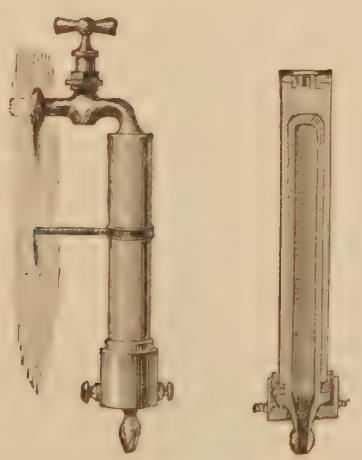

Fig. 101.—Chamberland's filter.

temperature causing the agar to dissolve readily, and rendering it very easy to filter; it also very rapidly sterilises potatoes.

Filtration in the cold.—It is often required to separate the products of metabolism from cultivations of micro-organisms, without subjecting them to the action of heat. For this purpose filters of (unglazed) porcelain or of porous earth are employed. The porcelain is usually in the form of a hollow cylinder, through which

the liquid to be filtered is either forced or sucked by means of a pump. There are numerous forms of these filters, of which the Chamberland model is well known, fig. 101. Such a filter may readily be attached to an ordinary water tap when it is desired to obtain pure water. With the same end in view a much more

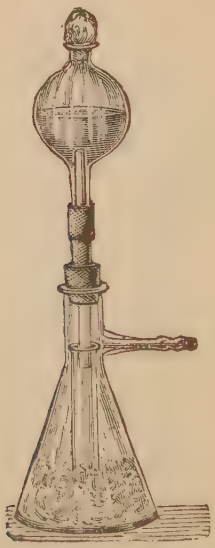

FIG. 102.—Porcelain filter.

The material to be filtered is placed in the upper receiver and then sucked through the porcelain bougie; the filtrate collects in the test tube immediately beneath the latter.

porous substance of diatomaceous earth is made into cylinders, to which are attached indiarubber tubes; the cylinders are simply placed in water, and by a syphon action the water slowly passes through. A simple porcelain filter for cultures is seen in fig. 102. Porous filters, like the above, are best cleaned by calcining.

Sterilisation at temperatures between 60° *and* 100° *C.*—In the case of blood serum, it is desirable to sterilise at a temperature just below that at which the albumins coagulate. For this purpose an incubator, water bath, oven, or the special serum steriliser of Koch, may be used. The sterilising has to be performed several times, and the process watched. To obviate the necessity of sterilisation, blood may be received directly through a sterilised cannula from an artery, into a sterilised vessel. The vessel is carefully protected, and the serum allowed to separate; it is then pipetted off into sterile flasks and sealed (see later).

Means of avoiding contamination.—After sterilisation, and in the case of cultivations, it is necessary to keep off the ambient micro-organisms. In the air micro-organisms appear to fall more vertically than might be supposed from their minute size. For in opening nutrient test tubes and flasks for the purposes of inoculation, it is remarkable how seldom contamination arises if the tubes are inverted or held horizontally during the process. Similarly a sterilised wine glass, the mouth of which is simply protected by a piece of paper, the edges of which are turned down, may remain for a very long time free from contamination. Recently the author had an opportunity of verifying, in a very complete manner, the accuracy of the statement that if the neck of a flask, containing a sterile putrescible substance, be drawn out and bent in the form of an S, the substance remains pure, although there is free access of air to the interior of the flask. In 1886 a flask was filled with sterilised urine, and had remained sterile and clear until the end of the year 1891, when the neck was accidently broken; then in a few days the urine became turbid and covered with a growth of moulds.

Cotton-wool is an effectual filter of the ambient microbes, and is the common material used in plugging test tubes, flasks, &c. Although it effectually hinders the ingress of micro-organisms, the higher fungi are nevertheless capable of penetrating and ramifying through the cotton stopper, and of then contaminating the interior. The mouths of sterilised vessels and cotton plugs should therefore always be carefully flamed and covered by a *proper sized* elastic or tin-foil cap, which has itself been carefully sterilised in 1 in 1000 sublimate. The cap, moreover, prevents evaporation and drying of the cultures or nutrient media. Sand and granulated sugar are used for filtering air, under special circumstances.

The Nutrient Media.

The media are very numerous, and include both liquids and solids, and may be either artificial or natural. Little need be said in this place of Pasteur's, Cohn's and Raulin's mineral fluids, which are all of them connected with very instructive and interesting histories. It may be mentioned, however, that Raulin found that a trace of silver inhibited the growth of *aspergillus niger*, and it is necessary to bear in mind that micro-organisms in general are very sensitive to their nutrient media, a special medium, or one having an acid or alkaline reaction, being very often necessary. Useful liquid and natural media are:—Hydrocele and other albuminous fluids, the aqueous humour of the eye of the ox, blood serum, milk, &c. It may be remembered that Koch largely employed aqueous humour and serum in his early experiments upon anthrax and tubercle.

Peptonised broth is, however, the most generally used of the fluid media.

Formula :—

Meat	500 grm.
Water	1 litre.
Peptone	10 grm. (1 per cent.).
Salt	5 grm. (0·5 per cent.).

A pound of lean meat, freed from fat, should be thoroughly minced, and after the addition of one litre of water, should be set aside in a cool place for twelve to twenty-four hours. The fluid is strained off, and the minced meat thoroughly squeezed in a press or cloth to make it part with as much of the extract as possible; there is usually a loss of several c.c. of fluid. To the extract add 0·5 per cent. of salt and 1 per cent. of peptone and dissolve. Neutralise with a few drops of a 10 per cent. or saturated solution of sodium carbonate. Place in a flask and plug with cotton-wool, and gradually warm up to the boiling point, then further carry it to 115° C., and maintain at this in the autoclave for ten minutes. Filter, test the reaction, and distribute into flasks as required. Plug and sterilise for ten minutes at 115° in the autoclave. Where a higher temperature than 100° cannot be obtained, the original meat extract should be kept at 100° for half an hour, and intermittent sterilisation should be resorted to. Instead of beef broth, chicken or fish broth is used when required. Broth may be used in the process of isolation of micro-organisms by the fractional method, and for inoculation purposes.

Gelatine.*—Formula :—

* The following is a modification, upon the side of simplicity, which I employ for making gelatine.

Dissolve the gelatine (100 grm.) in just sufficient boiling water, and

Meat . . .	500 grm.
Water . . .	1 litre.
Peptone . . .	10 grm. (1 per cent.).
Salt	5 grm. ($\frac{1}{2}$ per cent.).
Gelatine . . .	100 grm. (10 per cent.).

Prepare the meat extract as before, add the peptone and salt, but do not neutralise; boil to coagulate the proteids, then add 10 per cent. of fine gelatine which has been cut up in small pieces. Warm gently to dissolve the gelatine and then neutralise. Mix the white of an egg with about an equal quantity of water and add it to the luke-warm gelatine solution. Then slowly warm in a flask to the boiling point and maintain it at this temperature for half an hour. Filter whilst hot through a sufficiently large folded filter paper; the filter paper should be of stout and very good quality, it is also as well to moisten before filtering. In filtering gelatine the hot water filter is usually employed, but it is not necessary. The filtered gelatine is next distributed into test tubes and flasks as required, and it is as well that these should have been previously plugged and sterilised in the hot air oven (p. 427). To distribute proceed as follows:—Fix a funnel in a retort stand and attach a small piece of drawn out glass tubing by means of a short piece of india-rubber tubing over which a pinch cock has been slipped. Fill the funnel with the warm liquid gelatine solution, and run into

add it, together with the peptone and salt, to the watery extract of the meat; keep the whole at a temperature of 45° to 50° C., until the gelatine and peptone have thoroughly dissolved; neutralise; put into a glass flask and boil for three-quarters of an hour; filter whilst hot through good filter paper, well folded and moistened; (a hot filter is not necessary). The coagulation of the proteids of the extract clears the solution and does away with the necessity of the egg.

each test tube from one-fourth to one-third its volume of the mixture, in doing this carefully avoid smearing the mouth or even the upper part of the test tube. As many as forty to fifty tubes may be thus filled, whilst a few may be half and two-thirds filled; these will serve for plate culture making. As soon as the gelatine is distributed, the test tubes and flasks must be placed in the steamer and sterilised for ten minutes at 100° C., and this process must be repeated on the two following days. After the third sterilisation the major proportion of the tubes should be sloped whilst the gelatine is liquid, and then allowed to set; by this means a large surface of gelatine is obtained; the surface should commence at the junction of the bottom with the side of the tube and end about 1 in. to 1½ in. from the stopper. It is very essential that the mouths of test tubes and flasks which contain nutrient media, should be protected by some form of cap. These may be of india-rubber or simply tinfoil, which in either case should be sterilised before use, and before they are applied the mouths of the vessels and the cotton plugs should be flamed. When these precautions are taken, the media do not evaporate and the chances of accidental contamination are greatly diminished.

For the *luminous* and salt water bacteria the following formula is very good:—

Cod	500 grm.
Sea water	1 litre.
Gelatine	10 per cent.
Salt	3 ,,
Peptone	1 ,,

Agar.—This has several advantages over gelatine and should, therefore, be always kept in stock. Gelatine liquefies at a temperature slightly above 20° C.,

whilst agar can be incubated at a very much higher temperature; it can further be sterilised at a high temperature. On the other hand it is not quite so transparent as gelatine.

Formula:—

Meat . . .	. 500 grm.
Water . .	. 1 litre.
Peptone . .	. 10 grm. (1 per cent.).
Salt . . .	. 5 grm. (0·5 per cent.).
Agar . .	. 10 to 15 grm. (1 to 1·5 per cent.).

Prepare the peptonised broth in the usual way and alkalinise. Add the agar, cut up or in the ground form (best), and boil for three-quarters of an hour, stirring occasionally. Strain through a sieve. When cooled to about 40° stir in the white of egg mixture, place in the autoclave, and at first gradually heat to the boiling point, then maintain it at 120° for three-quarters of an hour. When ready filter through stout filter paper, using a moistened folded filter. Distribute; sterilise at 115° C. for fifteen minutes.

Nutrient gelatine may be stiffened by an equal quantity of agar. The addition of 5 per cent. of *glycerine* (Nocard and Roux) both to gelatine and agar, but especially to the latter, greatly enhances the nutrient value, many organisms as tubercle bacilli growing readily upon agar to which it has been added.

Potatoes.—Potato is, after gelatine and agar, the most useful medium, and owing to the great ease with which it can be prepared, a great favourite.

Method of preparation.—Wash a dozen or more potatoes, cut off each end, and with the special potato borer* (fig. 103), or with a suitable sized cork borer, punch out the potato. The pieces must then be well

* The borer should be plated.

rinsed in water, dried lightly on filter paper and placed in the special test tubes (fig. 104). The tubes are then plugged and sterilised, once for all, at a temperature of 115° for 15 minutes, or for three-quarters of an hour at the boiling point with a subsequent sterilisation for a shorter time.

A very great number of organisms grow well on potatoes, in spite of the fact that the reaction of the potato appears usually *acid* (author's experience). It is well, therefore, to always test the reaction of the potato.

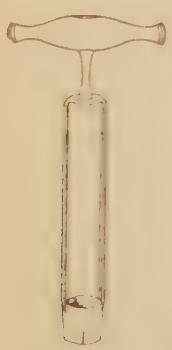

FIG. 103.—Potato borer.

FIG. 104.—Potato test tube.

Serum.—This is an indispensable medium under certain circumstances, and we should certainly counsel the laying in of a stock. It is especially valuable for the cultivation of tubercle and other pathogenic bacilli.

Method of preparation.—It is used in the *fluid* or the *coagulated* form, but in either case the initial preparation is the same. The blood of a slaughtered animal is received directly into a tall cylindrical glass jar,* which

* The student should take his sterilised vessel to the slaughterer's and see that he gets the blood as free from contamination as possible.

must be furnished with a proper stopper or lid, and the whole should have been thoroughly sterilised. The blood is set aside in a cool chamber to coagulate. On the following day the serum is carefully pipetted off, and some placed in sterilised flasks and the rest in sterilised test tubes, as in the case of gelatine and agar; the former are held as reserve stock of the fluid serum, whilst that in the test tubes is intended for coagulation. In the above method of preparation there are numerous chances of contamination, so that the serum has next to be sterilised. Owing to the fact, however, that the serum albumins coagulate at a temperature slightly above 70°, the sterilisation is necessarily prolonged, and moreover, the temperature must be kept constant. Special serum sterilisers are therefore usually employed, in which the temperature can be nicely regulated, but with care an ordinary water bath may be used. The serum in the flasks and tubes should be sterilised on three successive occasions, for one hour, at a temperature slightly below 70° (trial should be made at what temperature coagulation occurs). The serum in the test tubes may then be sloped and coagulated at a temperature between 70° and 80°. The coagulation requires care and time if a clear medium is wished for, as opacity soon sets in.

Numerous other media will naturally suggest themselves to the reader, such as eggs, bread, paste, hydrocele and pericardial fluids, milk, urine, &c. An undoubtedly useful, but little known basis, is **Kühne's coagulated silicate of soda,** it is a quite neutral substance, and is free from nitrogen, it can therefore be mixed with known quantities of food material. The fluid media of Pasteur and Cohn are also of a definite

composition. The formula of **Cohn's fluid** is the following :—

Distilled water . . .	200 grm.
Tartrate of ammonia . .	20 ,,
Phosphate of potassium . .	20 ,,
Sulphate of magnesia . .	10 ,,
Tribasic phosphate of lime .	0·1 ,,

Vessels used for the Storage of the Nutrient Media, &c.

Figs. 105-109 serve to give an idea of the various tubes and flasks employed to preserve the media in a steri-

Fig. 105.—Culture flask.

Fig. 106.—Culture flask.

lised condition. We have already spoken of the ordinary and the special test tubes, the most economical size of the former is 6 in. × $\frac{5}{8}$ in., and of the latter 6$\frac{3}{4}$ in. × $\frac{3}{4}$ in. A large number of flasks of various sizes should always be kept in stock. The special siphon flask (fig. 107) is often used to store serum ; but smaller pipettes can be readily made by the student and are very useful. They are made of glass tubing of various diameters, according to the size of receptacle wanted.

Take the glass tubing and draw from it in the flame a piece about 8 in. long, not including the tapering end which should be 4 or 5 in. long, and break off; about one inch in front of the tapering end, draw out the tube for 2 or 3 inches, thus making a constriction. Seal the extremity of the tapering end in the flame, and lightly plug the other extremity of the tube with cotton-wool. Sterilise in the hot air steriliser, or rapidly in the flame. To use, break off the sealed end, rapidly sterilise the tapering portion in the flame, and plunge it into the fluid

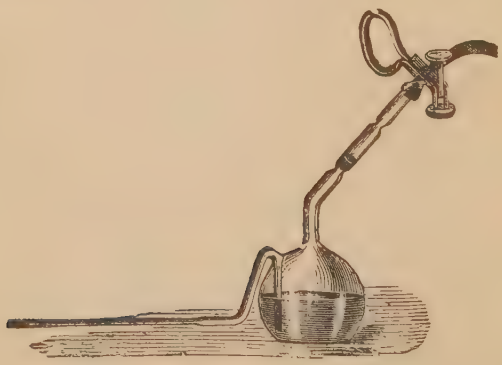

Fig. 107.—Siphon flask.

to be taken up (aqueous humour, serum, blood from a vein, &c.), then, when the ampulla is nearly filled, seal the tapering end, and applying the flame to the constricted portion, draw out, break off and seal. Virus may be preserved for a very long time in these ampullæ; they should be kept in a cool place.

The test tubes and flasks containing media, as well as the potatoes, should not be kept in too warm a place, as they tend to dry up.

It is useful to have always ready a stock of sterilised

plugged and capped test tubes, flasks and pipettes. The mouths of conical glasses and the glass boxes, such as are used for making plate cultures, may be wrapped

FIG. 108.—Pasteur flask.

FIG. 109.—Pipette.

round in paper and sterilised in the hot air oven ; the paper serves as a very efficient protection from the ambient micro-organisms.

CHAPTER II.

The Methods of Cultivation.

Inoculation of Media—Incubators—Drop Cultures—Inoculation of Animals—Post-Mortem Examinations.

Inoculation of media.—The inoculation of gelatine, agar, and of potatoes, is usually effected by the *platinum needle*. This consists of a short glass rod, as handle, into which is fused a piece of platinum wire, two to three inches long; the wire should not be too thick, but it is useful to have two sizes, both coarse and fine. Inoculation is thus performed. Take the tube to be inoculated and remove the cotton plug, in doing this rotate the tube and keep it at the same time *horizontal*, then rotate the mouth of the tube in the Bunsen flame for a moment, and replace the plug. Take the tube from which the inoculation is to be made and treat it as above; then holding this last tube in the left hand, with the right sterilise the platinum needle and lower end of the glass rod, then allow it to momentarily cool and with the little and ring finger of the same hand remove the cotton plug from the test tube, holding the tube as before in the left hand, and keeping it *horizontal* or *vertically downwards;* pass the needle rapidly and carefully into the interior of the tube and stick it into the nutrient medium to make sure that it is cool, when it is, remove a very small piece of the growth, rapidly cork the tube, and take up with the left hand the first tube and open

as above directed; pass the needle to the surface of the medium—then if this is a slanted surface or a potato, draw the needle from the bottom to the top, thus making a *streak* culture, or where the medium fills the lower portion of the tube, make a *stab* culture, by plunging the needle through the medium, care being taken to make it as straight and median as possible. Withdraw the needle and plug, and before laying down the needle sterilise it. Finally repeat the process of flaming the mouths of the tubes, and just singe the stoppers, then cap. The freshly inoculated tube is then to be labelled and dated and transferred to the incubator. In the above procedure dexterity and expedition are important, and it is necessary always to hold the tubes horizontal or with the mouths pointing downwards. When inoculating, more especially between fluids, it is usual to make a loop in the end of the wire in order that it may carry more virus; for the same purpose a sterilised pipette may be used. Sometimes it is advisable, as in the case of actinomyces and tubercle, to use a narrow spatula, in order to thoroughly *crush up* the growth when inoculating.

Incubators.—Incubators are well insulated chambers (fig. 110) surrounded by either a jacket of air or water; by means of a heat regulator they can be maintained at a constant temperature.

Much depends upon the form of regulator used. A most useful and non-breakable form is the *horse-shoe metal regulator* which was early used in the physiological laboratory of University College, London, and has since been adopted by M. Roux in the Pasteur Institute. A common form is the well known mercury regulator; it is, however, very liable to break, and then if the mercury comes in contact with the copper work

of the incubator, very considerable corrosion is the result; another form is the membrane regulator used by D'Arsonval, in which the expansion of a column of water presses an india-rubber or thin copper membrane

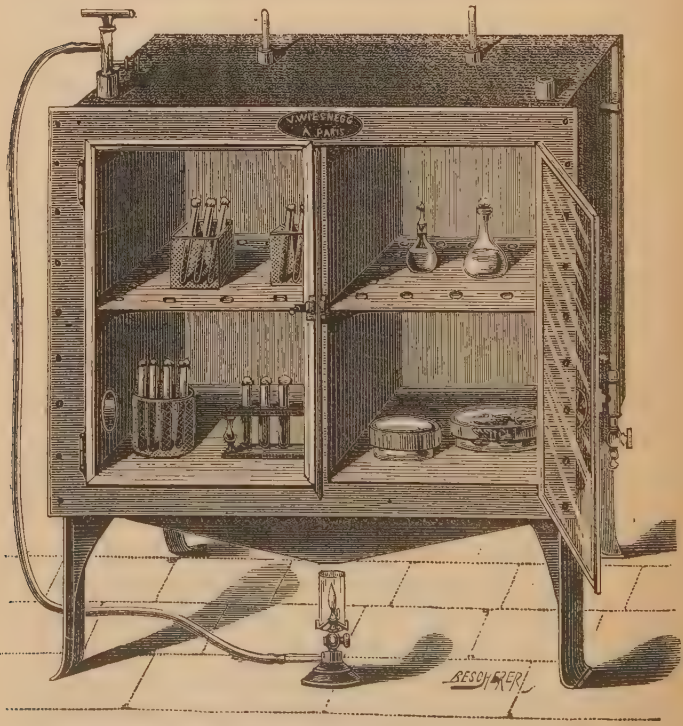

FIG. 110.—Incubator.

against the gas inlet. Where gas is not available, oil or the heat of a greenhouse may be used. It is often very useful, as well as easy, to maintain a small room at a temperature of 20° C. by means of hot water pipes or by one of the numerous forms of patent stoves. As

soon as the tubes in the incubator have well started growing they should be removed, for as before explained the media tend to become dry.

Drop cultures.*—This is a most useful form of cultivation and one which was much used by the pioneers of bacteriology. By its means the growth of the organisms can be studied under the microscope. It is necessary to have several micro-slides, hollowed in the centre, or slides to which glass rings, varying from the $\frac{1}{12}$ to $\frac{1}{8}$ in., are firmly cemented (to withstand heat and moisture). These slides are sterilised, and over each a sterilised cover-slip is placed; the slides may then be arranged on a slide rack made for the purpose, and the whole should be placed under a bell jar fitting into a glass dish; the bottom of the latter is covered by a fold of filter paper which is kept moistened with a 1 in 1000 solution of sublimate. The bell jar serves as a protective and moist chamber. When it is desired to make use of the slides, the cover-slip is removed from a slide with the forceps, and again sterilised by rapidly passing it through a flame; holding the slip horizontal, a drop of serum or other medium is forced on to the *under surface* by means of a pipette, the end of which points upwards, the slip is then replaced on the slide; when all the slides are ready, each cover-slip is inoculated by again removing it from the slide, holding it horizontal with the drop downwards, and then touching it with the needle containing the virus;

* One of the nicest and simplest drop culture chambers is made of a piece of stout glass tubing about $\frac{3}{4}$ inch in diameter drawn out at both ends. The opposite sides of the glass bulb are ground till large apertures are made; one side can then be cemented to a glass micro slide, whilst over the other the cover-slip is placed. Moist air or any desired gas can be circulated through the tube.

the cover-slip is replaced and may be more firmly fixed to the slide by means of the least trace of oil or vaseline. The bell jar containing the cultures may be placed in the hot chamber, and the slides should be examined

FIG. 111.—Bell jar for potato culture or moist chamber.

from time to time under the microscope, to see whether growth is advancing. It is sometimes necessary to place the microscope and the slide in a specially constructed box, which can be maintained at a desired temperature.

INOCULATION OF ANIMALS AND THEIR POST-MORTEM EXAMINATION.

Inoculation is an indispensable procedure in the study of the more important organisms or in any investigation of a pathogenic microbe. Leaving aside inoculation by *inhalation* and by *feeding*, there are two important methods, one the *subcutaneous*, the other the *intravenous*. In the former instance the skin of the thigh or abdomen is usually taken, or in the case of the feathered animals, the breast muscle. Very often, however, the tip of the tail or ear is chosen, as these are convenient places to watch the progress of the tissue reaction*; similarly the cornea and the anterior

* Thus if in preventive inoculation the local reaction is not the one desired and is dangerous, the part affected can be readily cut off without sacrificing the animal.

chambers of the eye are very useful under circumstances. Sometimes trephining is essential (hydrophobia). Previous to inoculation a small portion of the skin may be shaved and scrubbed with sublimate.

The syringes used are numerous, but any form which can stand boiling or hot air sterilisation, may be employed; Stroschein's, although not very delicate, is one which stands much wear and tear, is very cheap, and is readily sterilised.

Post-mortem examination.—In dealing with the pathogenic organisms great care should be exercised to prevent unnecessary dissemination of the virus. Thus a special dissecting tray should be used, such as one made out of zinc and having the margins perforated for the tapes: such a tray can be readily sterilised without deterioration. When the animal is small, it may be nailed to a piece of waste board, which is burnt with the animal as soon as finished. A saucepan containing boiling water, a Bunsen flame and a vessel containing sublimate, should be at hand in order to immediately sterilise or burn contaminated articles. The instruments required are forceps, scalpels, a pair of scissors, cautery irons, and a few prepared and sterilised pipettes. As an example of a post-mortem we may take a rabbit which has been subcutaneously inoculated on the abdomen with anthrax.

Make the autopsy as soon after death as possible, and proceed by nailing the animal on its back upon a piece of board. Observe on the abdomen a large œdematous swelling at the seat of the inoculation. With the cautery iron, cauterise a small area of the skin over the tumour, in order to thoroughly sterilise it; then take a pipette, break off the sealed point, pass through the flame and insinuate it beneath the skin at the prepared

spot, then suck up as much of the œdematous fluid as possible; repeat the process with other pipettes, seal the ends of some of them preparatory to making ampullæ; whilst one may be left open for immediate microscopic investigation. Cut into the tumour and observe the extreme œdema of the tissue as well as the hæmorrhagic staining. Open the abdominal and thoracic cavities and observe any congested or dark appearance of the viscera. Expose the vena cava, just cauterise the surface and insert the end of a pipette, and draw up some blood and make several ampullæ; the heart may be similarly pierced for the blood it contains. With great precaution (cautery and sterilisation of the instruments) snip out pieces of the liver and spleen and transfer to agar tubes to incubate. Make cover-slip preparations (see later) of the juice of the liver and spleen. Place pieces of the liver, spleen, kidneys, lung, heart, intestine or other organs into absolute alcohol to harden, and at same time spread small pieces of the mesentery over bits of cork and transfer to the alcohol. Plenty of alcohol must be used, or renew it within a few days. Make cover-slip preparations of the œdema fluid and blood, and also make some test tube inoculations directly from the œdematous tumour and the blood or from the ampullæ. Finally clean the instruments and burn the animal.

CHAPTER III.

Methods of Examination.

Staining for Micro-organisms. Cover-slip Preparations and Tissue Staining.

Only a few of the more important staining methods can be given here, for the rest the student must consult the proper text-books.

Reagents &c., required.—The following list of apparatus and reagents will be found indispensable for any microscopic investigation, viz:—

A large number of slides and cover-slips which have been thoroughly cleansed; the cover-slips must be first rinsed in nitric acid, and then, after rinsing in water, may be kept in stock in a glass jar of pure alcohol or ether; they must be dried when wanted for use with a perfectly clean rag, or with some of the finer varieties of tissue paper. It may be pointed out that handling the rag a few times is sufficient to make it greasy and to therefore impart its greasiness to the cover-slips, a condition which makes it impossible to spread an even film on the slips. A large stock of watch glasses for holding the stains and reagents; when in service these must be protected by another series of watch glasses or glass covers. A series of glass jars with lids to hold the more bulky reagents. Plenty of needles, a small pair of good forceps, one or two good *plated* section lifters.

The reagents required may be thus grouped:—

1. *For fixing and hardening:—*

Absolute alcohol (best); methylated spirit; osmic

acid (vapour 1 per cent. solution); Flemming's solution; saturated solution of $HgCl_2$ in $\frac{1}{2}$ per cent. salt solution.

2. *For embedding tissues :—*

Paraffin melting at 40° to 45° C.; saturated solution of paraffin in ether; methylated collodion; strong solution of thymolised gum.

3. *For mounting :—*

Solution of canada balsam in xylol; glycerine; Meyer's albumin for fixing sections to slides (equal parts glycerine and egg albumin and a little thymol, filtered).

4. *For dehydrating and dissolving out paraffin or fats :—*

Absolute alcohol; methylated spirit; equal parts ether and alcohol and ether.

5. *For clearing sections :—*

Oil of cloves; xylol; xylol 3 parts, and phenol 1 part; cedar, bergamot and origanum oils; glycerine.

6. *For decolorising :—*

Methylated spirit; nitric, hydrochloric and acetic acids; Gram's iodine solution (iodine 1 gramme, potassium iodide 2 grammes, water 300 c.c.); oil of cloves; aniline oil; alcohol 70 per cent., saturated watery solution of picric acid 30 per cent., and HCl $\frac{1}{2}$ per cent.

7. **Staining reagents.**—A stock of the more important stains should be kept in the dry state, as it is better in many cases to use freshly made staining solutions; the stains most frequently employed are those manufactured by Grübler of Leipsig. The solutions should be filtered before use.

(1) *Ehrlich's solution of gentian violet :—*

Gentian violet, 1 gramme
Alcohol, 15 c.c. } saturated solution.

Aniline oil, 3 c.c.
Aqua dest., 80 c.c. } = a saturated aniline oil solution, filtered.

Staining is effectual under one minute. It is very usual to treat sections and cover-glasses stained in this manner with Gram's iodine, the whole process being then called Gram's method. It is performed thus:— The cover-slip or section is stained from ½ to 1 minute in the gentian violet, then rinsed in water and transferred to a watch glass containing the iodine solution for about ½ minute; the section is again rinsed and placed in alcohol, until most of the stain has disappeared. the endeavour being made to remove the stain from everything except the micro-organisms, and then to *counter-stain* if necessary with a contrast colour (see below).

(2) *Carbol-fuchsine:—*

Fuchsine 1 gramme: alcohol 10 c.c.; carbolic acid 5 grammes; water 100 c.c.

This stain is especially used for Tubercle, and the bacilli found in Leprosy. Cover-slip preparations of tubercular sputum require ½ hour in the warm, and sections 24 hours or longer. Decolorisation is effectual in the case of tubercle with a 1 in 3 solution of HNO_3.

(3) *Methylene blue:—*

Watery and alcoholic solutions are very useful. The following are well known solutions:—

Koch's weak alkaline methylene blue solution:—

Concentrated alcoholic sol. of methylene blue	1 c.m.
Distilled water	200 c.m.
10 per cent. caustic potash solution . .	0·2 c.m.

Löffler's strong solution:—

Concentrated alcoholic sol. of methylene blue	30 c.m.
Caustic potash 1 per cent.	100 c.m.

Sahli's strong borax solution:—

Saturated watery solution of methylene blue	24 c.m.
5 per cent. borax solution	16 c.m.
Distilled water	40 c.m.

The following counter stains are indispensable :—

(1) Solutions of *hæmatoxylin* and *logwood*.

(2) Watery and alcoholic solutions of *eosine*. This is especially useful in cover-slip preparations of the blood as the red corpuscles give a very distinctive reaction.

(3) *Biondi's fluid*.

(4) *Carmine* and *picro-carmine*.—In counter or contrast staining with picro-carmine (a double stain, carmine and yellow), the following plan may be adopted either before or after staining the micro-organisms. Thus stain the sections ½ to 1 minute in *Orth's carmine*, then well wash out all excess with the *alcoholic picric acid solution* (p. 452), the section assuming a very light pink tint. Next proceed to stain with saturated watery solution of *picric acid*, allowing as long as possible. Wash in water and stain the microbes with gentian violet, pass through Gram's iodine, wash, just dehydrate with alcohol, and quickly decolorise with oil of cloves, then wash in xylol and mount in xylol balsam; if Löffler's blue is used, decolorise in aniline oil.

(5) *Picric acid* dissolved in water, alcohol or oil of cloves, is a very useful yellow counter-stain. The same may be said of *methylene blue*, which may likewise be dissolved in oil of cloves.

Cover-slip preparations.—Spread a very thin film of the substance to be examined upon a cover-slip (properly cleaned, see above), or place a small quantity of the substance, such as sputum, between two cover-slips and then slide them apart. Or in the case of blood smear a very thin and uniform layer on by means of a glass rod. Let the film thoroughly dry. Take the slip up in the forceps and pass it through the flame of a Bunsen three times to fix the film; fixing may also be done by dropping on the solution of ½ ether and alcohol.

Then stain film downwards in a watch glass containing the dye, say gentian violet, remove in about ½ minute and rinse in water; then transfer to a watch glass of the iodine solution, rinse in water and then in alcohol until nearly all colour has disappeared; finally in the case of blood preparations, stain it for a couple of minutes in a watch glass containing a dilute watery solution of eosine; allow to dry and mount in balsam solution.

Section cutting and staining.—Having hardened in alcohol (absolute preferably) only just sufficient tissue necessary (a process which requires a few days) thoroughly dehydrate by another immersion in absolute alcohol; then transfer to a mixture of alcohol and ether for a few hours, then to ether, and finally to a saturated solution of paraffin in ether for 12 hours; the vessel containing the latter should be kept in a warm place and as much paraffin added as the ether will take up. Then the piece of tissue must next be transferred to paraffin melting at 40, or just above, and kept in this in the incubator for 12 or 24 hours. This process requires considerable care and attention and must not be hurried. To cut, place the tissue upon the carrier of the microtome embedded in plenty of wax. The sections must be as thin as possible; then if they are friable, paint one side of a cover-slip with a *very small quantity* of Meyer's albumin (p. 452) and press the section down upon it, undoing all folds; the cover-slip must then be gently heated for an instant over a flame to just coagulate the solution, when this is done the cover-slip may be treated in every respect as a section. Place the sections in ether to dissolve the paraffin, then in absolute alcohol. Stain with picro-carmine and gentian violet according to § 4 p. 454. In the case of tubercle stain for 24 hours in

carbol-fuchsine decolorise in 1 in 3 HNO_3, and after washing counter-stain with methylene blue.

The quicker way of cutting sections is the common one of embedding in gum and freezing, but it is not so accurate, owing to liability of contamination. The collodion or the combined collodion and paraffin methods are very good.

CHAPTER IV.

The Bacteriological Examination of Air, Water, and Soil—Anaerobic Micro-organisms.

Air.

Many of the methods adopted for the examination of

Fig. 112.—Petri dish.

Fig. 113.—Filtering tube to keep back the bacteria.

the ambient micro-organisms are both easy and instructive. One of the simplest and self-evident, consists in

exposing a sterilised surface of gelatine to the air, for a known period. Glass dishes (Petri's dishes) with lids, fig. 112, of various sizes are made for the purpose; they should be of clear glass, and it is an advantage to have each surface polished. They are sterilised in the hot oven and then sufficient nutrient gelatine to cover the bottom is rapidly poured into them, in doing this the lid is only just raised to permit of the pouring in of the gelatine. The gelatine should be made to set as soon as possible and the boxes should then be kept for two

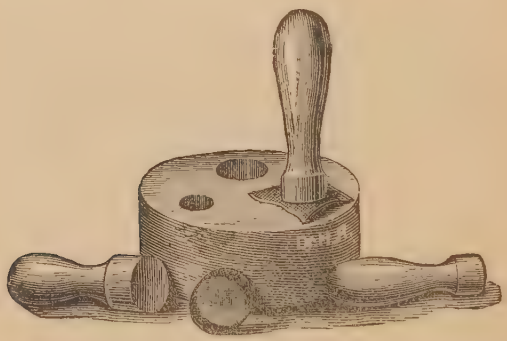

FIG. 114.—Punch for making the gauze wads which fit in the filtering tube.

days in a moist atmosphere, to see whether they remain sterile. When it is desired to make an observation, the lid of the box is taken off for a second or longer, then replaced and put into the warm moist chamber to incubate. Very numerous forms of fungi, according to the locality, rapidly develop. The moulds are early identified; amongst the micro-organisms are observed some which liquefy the gelatine, others of various shades of red, yellow and other colours; some assume definite forms of growth. The number of separate colonies

should be counted, a process which may be facilitated by a hand lens, or by placing the box on the stage of the microscope and examining with a low power. The number of distinct species may also be ascertained, and from these single cultures should be made; in this manner a large number of interesting micro-organisms can be readily obtained from the air.

Other methods of air analysis consist in drawing known volumes of air by means of some form of aspirator over solidified gelatine or through *liquefied gelatine*, *cotton-wool*, *sand*, or *granulated* or *powdered sugar*. In

Fig. 115.—Petri's apparatus for examination of air.

Hesse's apparatus the air is drawn through a glass tube some 18 inches or more in length, the floor or the whole of which is covered with sterilised gelatine; the micro-organisms are deposited on the gelatine surface and form colonies which are counted. In Petri's apparatus the air is drawn through a column of sand; the sand is then shaken up with liquefied gelatine and run on to a plate or spread out in an Esmarch tube (see later). In Frankland's apparatus the air is sucked through a plug of glass-wool, which is afterwards thoroughly shaken up with gelatine. In Sedgwick's and in Tucker's

methods, the air is drawn through a column of granulated sugar, which when mixed with the liquid gelatine dissolves (an advantage over the sand employed by Petri), leaving the bacteria to develop. Sedgwick's apparatus may be said to consist of an open tube one inch in diameter and six inches in length, one end of which is drawn out into a mouth in such a way as to present a fair sized shoulder from the point where the drawing out commences; the other extremity is also pulled out into a tube of about one quarter-inch diameter, and to this eight inches of quarter-inch tubing is annealed. The narrow limb of the tube is filled with 10 c.c. of sterilised granulated sugar and both ends of the tube plugged with cotton-wool; the whole is then sterilised. Having removed the large cotton stopper a known volume of air is sucked through, and then sterilised liquefied gelatine, sufficient to coat the interior of the wide portion of the tube, is poured in, and the cotton plug replaced; whilst the gelatine is still liquid the sugar is shaken down into it where it dissolves, and then by turning the tube round under a stream of water, (as in making an Esmarch tube), the gelatine is made to coat the interior; when the colonies appear they can be readily counted. Other apparatus are those of Miquel, of Schönauer, and of Strauss and Würtz.

Water.

A ready and easy method of ascertaining the relative number of micro-organisms in a sample of water, is to take a gelatine tube $\frac{2}{3}$ filled with sterilised gelatine; the gelatine is just liquefied and a small measured quantity (say 1 c.c.) of the sample of water is added, and

distributed well throughout the gelatine by careful shaking. The tube is set aside in a warm place and colonies soon appear. When it is desired to count the colonies and to thus come to a more accurate conclusion as to the number of bacteria in a sample of water, the gelatine must be spread upon a plate or line the interior of a tube. A sample of the water is taken up in the sterilised pipette, but if there is any delay in making the cultures immediately, ampullæ of the water may be made (p. 442). By means of the pipette 1 c.c. or less of the water is mixed with some sterilised liquefied gelatine in the test tube, the contents are then poured into a sterilised Petri box; the colonies can subsequently be counted and an endeavour made to isolate and identify the growths (see later). In Esmarch's method the tube containing the liquefied gelatine to which the water has been added is turned round, under a stream of cold water or on a block of ice in order to cause the gelatine to solidify on the interior of the tube; to obtain a uniform coating some practice is required; the outside of the tube (or of the box as in the preceding method) may be divided into small squares with pen and ink and the colonies counted, by the aid of a lens if necessary. The most suitable form of tube for performing the rolling is one in which a shoulder has been made, as in fig. 116.

Soil.

A very small sample of earth may be shaken up with sterilised liquefied gelatine and an Esmarch tube made; or the contents may be poured out into a Petri box. An endeavour may be made to separate the microbes

from the earth by careful washing in sterilised water, the latter may then be mixed with the gelatine.

In examining *foods*, streak cultures may be made with the platinum needle.

Anaerobic Micro-organisms.

There are some organisms which thrive best in the absence of oxygen, and indeed in some cases the oxygen has an inhibitory action upon their growth. Owing to this circumstance, the class of *anaerobic* micro-organisms as they are called, is not a large one, but they include two very pathogenic micro-organisms, viz., the bacilli of *tetanus* and of *malignant œdema*. As is well known different groups of fungi succeed one another in a nutrient medium undergoing decomposition. The moulds early make their appearance to be succeeded by the bacteria ; whilst the former are vegetating there is very little smell of decomposition, but when they have died away and their place has been taken by the schizomycetes, gases begin to be formed. When the substance undergoing the decomposition is well exposed to the air, the oxygen undoubtedly masks the exhalation of the foul smelling gases by thoroughly oxidising these odorous bodies. The removal of the foul smelling gases favours the further growth and multiplication of organisms—the aerobic, whose activity depends upon the presence of oxygen. But if the foul smelling gases tend to collect, as they do in stagnant water and mud, in cesspools and in drains, the conditions of growth of the aerobic organisms become exhausted, and they are replaced by a new class—the anaerobic. These continue the putrefactive processes

still further and give rise to an abundance of stinking gases; Pasteur even maintained that they were the chief cause of *putrefaction*.

The hygienic lessons to be deduced from these facts are obvious and important :—*The free access of air favours, by its oxidation, the removal of odours during the process of decomposition; stagnation, on the other hand, favours putrefaction along with the production of odourous gases, and in the stagnating filth of cesspools, drains, &c., the germs of tetanus and malignant œdema find a resting place.*

The anaerobic organisms are artificially cultivated

Fig. 116.—Tube for making anærobic cultures.

in media in which the free oxygen has been expelled, and to which the free access of air is hindered as much as possible; or they are cultivated in an atmosphere of hydrogen.

Methods.—These are numerous. A sterilised gelatine tube may be carefully boiled over a flame for a few minutes to expel the free air; it may then be inoculated with the organism, and sterilised oil, paraffin, or gelatine poured over to further exclude the air. Or a large test-tube containing sterilised gelatine is heated and

then connected to the exhaust pump; in addition a stream of hydrogen may at the same time be passed through the gelatine; this process may be repeated several times, till the gelatine is thoroughly free from air. The tube is then inoculated, and the inoculated gelatine drawn up into long ampullæ and sealed, or the tube itself is sealed. In the case of tetanus and malignant œdema, the development of gas bubbles reveals the growth of the organisms. Or the inoculated gelatine is spread over the bottom of a glass flask and a slow stream of hydrogen, from a Kipp's or other apparatus, kept circulating over it.

CHAPTER V.

General Morphology and Biology.

In the preceding pages the apparatus and the methods necessary for the study of the micro-organisms were passed in review; it remains now to discuss the peculiarities and behaviour of the latter upon the nutrient media, and in animal tissues, or in other words, their relationship to disease.

The following table drawn up by Flügge serves to give an idea of the mode in which bacteria might be studied:—

I. The conditions necessary to their life, including:—
   - (*a*) The nutrient materials.
   - (*b*) The influence of oxygen.
   - (*c*) ,, ,, of temperature.
   - (*d*) ,, ,, of light.
   - (*e*) ,, ,, of pressure.
   - (*f*) ,, ,, of electricity.
   - (*g*) ,, ,, of movement.

II. The result of the life of the microbes as seen in:—
   - (*a*) The assimilation.
   - (*b*) The tissue changes.
   - (*c*) The growth.
   - (*d*) The multiplication.
   - (*e*) The fructification.
   - (*f*) The peculiar products of excretion.
   - (*g*) The fermentative processes.
   - (*h*) The relation to disease.

III. The winding up of the life or *involution*.

The media.—Numerous species of bacteria have a characteristic mode of growth. In the first place there are certain micro-organisms which liquefy gelatine, so that they may at the outset be divided into the *gelatine liquefying* and *non-liquefying*. The extent to which liquefaction may occur may vary however.

In the case of a stab culture in gelatine, the growth may be uniform along the track, or in isolated colonies, or may branch out like a pipe brush ; or the growth on the surface proceeding more rapidly, a nail-shaped growth results ; the liquefaction may be funnel-shaped or proceed uniformly from the top ; in the case of Bacterium Zopfii a beautiful feather like growth is assumed. On agar likewise the growths may be striking ; thus anthrax has a most characteristic frosted appearance ; Bacillus subtilis rapidly forms a wrinkled membrane ; the ray fungus assumes a scab like growth. On the potato, the shining inconspicuous growth of the typhoid bacillus is very characteristic. In broth some micro-organisms produce great turbidity, and this may assume a diffuse, flocculent form, or a sediment rapidly settles to the bottom, or a scum is formed on the surface. Some micro-organisms produce gas bubbles in the nutrient substance ; some cultures smell sweet, others foul. Certain micro-organisms grow with great difficulty upon certain media. Bacterium Zopfii assumes its characteristic feather like appearance upon gelatine but not on agar. Some microbes are very sensitive to the reaction of the medium. In the case of Bacillus pyocyaneus, grown upon potato, the presence of ammonia vapour very rapidly induces the green coloration. Similarly lactic acid favours the development of the coloration of the bacillus of blue milk.

In the case of the cromogenic bacteria, *oxygen* increases the coloration, thus merely shaking a tube of liquefied gelatine of B. pyocyaneus produces a deep green coloration; similarly the phosphorescence of the phosphorescent bacteria is increased on shaking, and the fluorescence of B. fluorescens becomes marked upon the free access of air. The anaerobic micro-organisms thrive best in the absence of oxygen.

The most favourable temperature for growth ranges from 20° to 40° C. At higher temperatures the properties of most of the organisms become altered; thus anthrax at high temperatures (42°) loses its virulence to a remarkable extent. Chauveau describes three degrees of temperature, "favourable," "impeding," "suppressive," thus for B. anthracis 42° to 43° is impeding, whilst 47° inhibitive.

Light appears unfavourable for spore formation; it is stated (Koch) that direct sunlight kills tubercle bacilli.

The products of the bacteria.—When the bacilli of anthrax and tuberculosis were first found inseparably connected with these diseases, and when subsequently a large number of other contagious diseases were proved to be due to a specific organism, an immense advance was made in the pathology of disease and in **preventive medicine.** Since these discoveries, numerous investigators have been at work to find out the way in which the bacilli brought about the disease. At first it was assumed, as in anthrax, that the bacilli appropriated to themselves the oxygen in the blood, and so starved out the system. This, however, could not explain the severe toxic symptoms observed in septicæmia, and in diphtheria, where the contagium vivum appeared limited to one spot, and was not to be found in the nerve tissues, or in the liver, heart, and

other viscera, although these were profoundly altered. As is known, bad meat, fish, sausages, pork pies, cheese, milk, and other articles of diet may give rise to violent symptoms of poisoning; and as early as 1856 Panum had isolated from watery and alcoholic extracts of putrefying flesh certain poisonous substances. In 1868 Schmiedeberg and Bergmann obtained a nitrogenous body resembling the vegetable alkaloids, which they named *sepsine*. Later Selmi very carefully studied the physiological action of these alkaloidal substances, to which the name of *ptomaïnes* was given. Brieger worked most carefully at them, and succeeded in obtaining some beautiful crystallisable bases (ptomaïnes) from a variety of putrefying nitrogenous substances, and from cultures of pathogenic fungi. It thus became recognised that in the decompositions effected by bacteria, certain extremely poisonous substances might be elaborated from the proteid materials, and that not only might these be manufactured in the culture tube, or in the dead body, but also in foul wounds where their absorption produced toxic symptoms. In the meantime Gautier (1880) found that similar toxic alkaloids might be formed as the result of the activity of the cells of the living organism; he termed them the *leucomaïnes*. Brieger obtained putrescine and cadaverine from cultures of the cholera bacillus, typho-toxine from the typhoid bacillus and tetanine from tetanus; he gave to them the name of *toxines*. It has, however, not always been possible to isolate a crystallisable alkaloid, even when, as in diphtheria, there are all the signs of the absorption of a virulent poison. Another train of investigation led to the explanation of this, and at the same time threw much light upon the subject of *vaccination*.

Wooldridge by cultivating anthrax bacilli in a solu-

tion of tissue fibrinogen, obtained a substance which conferred *immunity* to an animal subsequently inoculated with anthrax. Martin obtained in cultures of anthrax upon alkali-albumin an alkaloid and albumoses, and suggested a relationship between the two; thus the albumins may first be converted into albumoses, *tox-albumins* or *-albumoses* in the case of the poisonous varieties, and then into the ptomaïnes (compound of ammonias), or *toxines*. In anthrax it appears that the alkaloid is the most poisonous product, whilst the albumoses are less so, and it is suggested that the latter may in the case of anthrax act as a vaccine. Working upon diphtheria, Löffler found that a porcelain filtrate of a pure culture of the diphtheritic bacillus gave rise to the symptoms of diphtheria, and with Roux and others concluded that one of the active principles of the filtrate was a *ferment*. Martin further has recently separated from pure cultures, and from the diphtheritic membrane, blood and spleen of diphtheritic patients, albumoses and an *acid*, but no alkaloid; these substances are capable of producing certain definite symptoms, but the albumoses are the most powerful; more powerful than either, however, is the ferment. Thus, in diphtheria it may be that the ferment splits the proteids into albumoses and that one of the end products of these is the acid and not the alkaloid as in anthrax.

In the above we have briefly alluded to the subject of *vaccination* and *immunity*. For hygiene in general, both are of the highest importance, occupying as they do, the first place in *preventive medicine;* unfortunately, however, space does not permit us to enter upon a discussion of the numerous theories that have been brought forward, and we would earnestly counsel the student of hygiene to seek for fuller information in the writings of those

who have devoted themselves to this all important subject. We know that of a number of individuals exposed to a contagious disease, some remain unaffected, others sicken and a few die. The infant is more liable to a large number of infectious diseases than the adult. The young rat is susceptible to certain inoculations, the adult rat is refractory. Some sheep readily become affected by anthrax, others are immune; differences even exist in the case of town and country mice. In man the proneness to become tuberculous is often hereditary. In some animals tubercle makes a very slow progress, in others a very rapid one; sometimes it remains confined at other times it spreads. In anthrax in man, the local reaction is so limited that there is sufficient time to remove it before general infection occurs; in the rabbit very large œdematous tumours are formed at the seat of inoculation, whilst in the guinea pig the local reaction is not so great and the general infection is more rapid. Before the bacillus can find a footing the ground must be prepared for it; thus in the case of the diphtheritic bacillus it is especially an ulcerated surface that is attacked, a surface in other words in which it finds, as has been pointed out, the proteid material which it can act on with its ferment. The above are some of the questions which present themselves at the outset of a discussion upon immunity. We seek, however, to produce immunity artifically by *vaccination* and even to check the progress of a contagious disease by an antidote or by what has been termed an *antitoxin*. It has been mentioned above that the bacillus of anthrax produces a vaccine and a toxine, the former an albumose which may be as has been suggested a less virulent form of the latter; it is known that the serum of animals vaccinated against

anthrax and hog cholera tends to confer immunity upon unvaccinated animals; and that a *subcutaneous* inoculation of a certain specific disease may produce immunity, whilst an *intravenous* causes death. It is further known that *attenuated virus*—attenuated by heat, drying, prolonged keeping, addition of antiseptics, &c.—confers a certain degree of immunity. The remarkable discovery of Jenner's, that inoculation with the mild cow-pox protects for a very long time against virulent small-pox, has received the strongest support by the above more recent observations. The specific virus at some stage of its existence, elaborates something which like certain drugs appears to have a remarkable influence on the cells—a stimulating influence it has been called.

General Morphology.

Micro-organisms are simply divided into the following divisions:—

Micrococcus.
Bacterium.
Bacillus.
Vibrio.
Spirillum.

Segmentation is transverse. In the micrococci division may take place in different planes. After division the elements usually separate, but they may remain united in threads as in the case of bacilli, or in chains as in the *streptococci*. In the *staphylococci*, the cocci form irregular groups. When division occurs in more than one direction, and the segments remain united, tetrad and *sarcinæ* forms result. Very often two cocci remain united—*diplococci*. Large colonies may remain united

by the presence of a gelatinous substance, the aggregation is then termed a *zooglea;* the zooglea may assume a very definite form. Many of the diplococci and sarcinæ, and some of the bacilli possess an outer faintly staining envelope; they are said to be *encapsuled*. A large number of micro-organisms are furnished with *flagellæ*.

Amongst the higher bacteria, as cladothrix, polymorphism is common, coccal, bacillary, and spiral forms being met with. Even amongst the less highly developed forms as anthrax, bacillus pyocyaneus, &c., these are numerous "form phases"; and what is most interesting these phases appear greatly dependent upon surrounding conditions. Thus Bacillus anthracis may in serum be made to assume a beautiful filamentous type, in the segments of which spores form; but in the blood and tissues it occurs only in the segmented state, and no spores are produced. The glanders bacillus is said to differ in a fresh tumour and in an old tumour in winter; and the addition of glycerine and sulphate of iron to broth containing a culture of this bacillus gives rise to clove-shaped forms. The vibrio of septicæmia of Pasteur is rod-like in the subcutaneous tissue, but filamentous in the blood. Again, anthrax in the normal frog occurs in the usual bacillary form, but if the temperature of the animal is kept elevated, hyphal forms are obtained. This difference in form also very often implies a difference in physiological action. Bacillus pyocyaneus offers a whole series of "form phases" intimately dependent upon minute changes in the chemical composition of the surrounding medium. For instance, the addition of 0·20 to 0·25 per cent. of naphthol, or of 0·50 per cent. thymol, gives rise to a growth in which the rods are much larger. Potassium

dichromate 0·10 to 0·15 per cent. causes the filaments to become still longer and degenerate, or *involution* forms appear. The addition of 4 to 5 per cent. boracic acid gives rise to filamentous, comma and spirillum-like forms. The addition of creosote or of salicylic acid causes a coccus growth. Polymorphism is extremely common amongst micro-organisms and is dependent upon very many causes. According to Billet, in the case of cladothrix, the motile spirilla forms are most abundant when putrefaction is present. When the medium is becoming exhausted, zooglea and involution forms make their appearance.

Spore formation.—Spore formation occurs in many of the bacilli, and may lead to changes in form of the segments; thus they may become beaded, club or dumbell-shaped. The spore is more resistant to external influences, *i.e.*, heat; it requires a period of rest before germination and usually transportation to a fresh soil.

CHAPTER VI.

The Infective Processes in Man and Animals.

It is intended in this section to point out the leading tissue changes in some of the more important specific diseases, but the student is again recommended to seek the textbooks devoted to the infective processes both in man and in animals, as well as the allied subject of *meat inspection*.

The active tissue changes of the infective processes are all included under the term *inflammation*, and the great characteristic feature of this is, in the acute processes, the *massing of leucocytes*, and in the chronic the formation of *granulation tissue* consisting of proliferating tissue corpuscles, leucocytes, macrocytes (macrophages), and giant cells. The phenomenon of leucocytic massing has been interpreted differently by various great Teachers and their Schools. Thus Virchow regarded the cell increase as a reaction to a stimulus; Cohnheim that the walls of the vessels were damaged and so permitted the escape of leucocytes, and lastly Metschnikoff states that the microbe, by the aid of its toxine, causes the arrival of a large number of leucocytes upon the battle field. For this last observer and for his followers, the leucocytic massing is not passive, but depends upon direct attraction between the leucocyte and the substances excreted by the microbes. This attractive power is spoken of as *chemotaxis*, and although in the large number of cases the chemotaxis is attractive or *positive*, yet it seems as

if in a few cases there was a repellent action, so that no leucocytes appear at the focus of inoculation. It is argued by Metschnikoff that the migratory cells—leucocytes and macrocytes, are phagocytic, that they take up and digest the microbes.

Diphtheria.—In diphtheria the virus rapidly leads to the formation of a tenacious or stiffened mass of dead tissue, which can often be peeled off in the form of a distinct membrane.* The necrotic mass consists both of the coagulated tissue elements and of the coagulated exudation from the vessels. The fibrin may be in the form of a network, or with the corpuscles be reduced to a firm granular mass. *Coagulation necrosis* has been applied to the process. The microbe is Löffler's bacillus, and is found beneath the membrane, numerous non-specific bacteriæ being encountered in the necrotic tissue. The bacillus may be stained with Löffler's blue and the tissues decolorised with a half per cent. solution of acetic acid. According to Roux and Yersin it suffices to obtain cultures, to transfer a piece of the membrane on to solid serum by means of a minute spatula; the tubes are incubated at 33° C. to 35° C., minute colonies rapidly begin to appear and enlarge; it is said that the colonies of the diphtheritic bacillus are the only ones which appear within the first twenty hours.

Pneumonia.—The reaction in the lung as seen in man consists of an intense inflammation, characterised by the presence of enormous numbers of leucocytes and of much coagulated fibrinous material. The alveoli are distended by the exudations and the lung is solid and engorged.

* As previously mentioned the surface often appears ulcerated, prior to infection.

Fränkel's micrococcus or bacillus appears to be the most constant excitant. It is a diplococcus, or perhaps bacillus, for the segments are slightly elongated and lance shaped; a capsule may be demonstrated. They may be stained with alkaline methylene blue, or by Gram's method. The growth on nutrient media is feeble, and difficult to keep alive; inoculated into rabbits, when virulent, it produces septicæmia.

Fränkel's diplococcus resembles Friedländer's diplococcus which is also found in the lungs, but the latter grows much more rapidly, forming in stab cultures, nail-shaped growths. Rabbits are refractory to it.

Pleuro-pneumonia.—This is peculiar to the bovine species, and one attack is said to confer immunity. A specific organism appears not to have been isolated. The tissue changes in the lung consist of a very pronounced *interstitial* and sometimes of an intra-alveolar (as in man in pneumonia) inflammation, marked by the presence of much leucocytes and fibrin; the pleura is the seat of an acute fibrinous inflammation; the lung is solidified and greatly enlarged.

Typhoid.—The virus of this intestinal disease is the bacillus of Eberth. It grows upon gelatine in the form of very flattened and shining colonies; it does not liquefy the gelatine; on potato it produces a very characteristic growth, rapid in its development, but scarcely to be detected were it not for the glairy wet-like reflection it gives the surface of the potato. The rods are short, but on cultivation threads may be formed. A spore is formed at the end of a rod, and minute flagellæ may be demonstrated with suitable staining; the bacilli are motile. They may be stained with alkaline methylene blue or with gentian violet, but they are decolorised by Gram's method. They may be

separated from the stools by plate cultures, and reliance placed upon potato growths for their identification. The bacilli are not easy to stain in sections, they occur in characteristic little clumps, both in Peyer's patches and in the spleen.

As definite changes do not appear to regularly follow the inoculation of the typhoid bacillus in animals, it can readily be understood that the identification of Eberth's bacillus is no easy matter when taken either from dejecta or from water, and much has already been written concerning its close resemblance or even identity with the Bacillus coli communis, one of the common parasites of the intestine.

Cholera.—The microbe of this disease is the comma bacillus of Koch. It may be found in the form of short curved rods, or in the larger spirillum form; there is in fact considerable variation in the size of the segments; the spirillum is the more motile form, and it is due to the presence of the active movements, so that it is better to study the organism in the living state in drop cultures. On gelatine, a thread-like growth follows in the track of the needle in stab cultures; liquefaction slowly commences at the top and a round-headed nail-like growth results. The organism also grows upon agar and potato. The bacillus is most abundant in the intestine in the early stages; later when ulceration and gangrene is set up all kinds of micro-organisms are found. A flake of mucus from the "gruel water" stools may be shaken up with gelatine and plate cultivations made; the colonies are then identified and isolated. The bacilli may be stained with alkaline methylene blue.

Feeding experiments on animals do not always give definite results, for in the case of the cholera bacillus, as indeed in the case of other microbes, the gastric

juice acts as a bactericide. It has been found, however, that although the comma bacillus is aerobic, it can be accustomed to an anaerobic existence and that then the virulence is increased. The anaerobic conditions are met with in the intestine, the aerobic when the dejecta have passed out. Several methods of protective inoculation have been devised; Haffkine attenuates the virus by cultivating it in a slow current of moist air; when this is injected under the skin of a guinea pig it produces a local tumour, when this has subsided it is found that the animal reacts less to the injection, and that after two or three injections it is immune; similarly injected into the human subject it produces a local œdema. The same worker, by gradually accustoming the bacillus to grow upon rabbits' serum, serum that is, which is inimical to this bacillus, obtains a culture which produces choleraic symptoms and death in the rabbit, when before this was impossible. He also increases the virulence of the microbe by passing it through a series of guinea pigs. Klemperer attenuates by heat at 70° C. for two hours, or by passing an electric current through growths. By interfering with the natural secretions of the stomach by the administration of alcohol, or of soda and opium, infection by the mouth has been produced.

Chicken cholera.—The microbe is a very short rod and when inoculated into the fowl produces drowsiness, great weakness, and finally death; there may be diarrhœa. Guinea pigs are refractory, only developing a local reaction.

Pig cholera or typhoid, swine erysipelas, Rouget du Pore.—The microbe is a small bacillus similar to mouse septicæmia. House mice and pigeons are very susceptible, guinea pigs and fowls are very

refractory. Pasteur found that the virus was increased by passing through pigeons and lessened by passing through rabbits; the virus obtained from the latter he employed to produce immunity in young pigs.

Glanders.—The bacillus is very difficult to stain in sections; soaking for 24 hours in alkaline methylene blue being necessary. On potato the growth has a yellowish brown appearance but appears white in the other media. Guinea pigs, horses, asses and man are susceptible; in the rabbit there is a local lesion, but the virus fails usually to generalise.

Anthrax.—We have already mentioned the pleomorphism of the bacillus. Stroke cultures on gelatine show characteristic small colonies with undulating margins (medusa heads) and of a frosted appearance when viewed by transmitted light. Stab cultures have a pipe brush appearance and there is not much liquefaction of the gelatine. Adult dogs, white rats, Algerian sheep and frogs are immune. For staining, &c., see Chap. III.

Tuberculosis.—This occurs as a miliary lesion, or locally. Infection occurs through the lungs by the alimentary tract and by external wounds. The tissues which are often attacked are the lungs, intestines, tongue, the bones and joints, epididymis, lymphatic glands and serous surfaces. The lesion consists of a typical granuloma, giant cells, macrocytes (epithelioid cells) proliferating endothelial and connective tissue cells, leucocytes, &c.

Central necrosis of the granuloma is usual and results in the formation of the very characteristic *caseous* material. The bacilli may be found at the spreading edge of the caseation, free or in the macrocytes or giant cells; it is usually difficult to demonstrate any-

thing in the caseous foci themselves, nevertheless this material may contain spores, as is proved by inoculation. The bacillus is very slender and often appears distinctly beaded. It is best grown upon glycerine agar, and a tube may be inoculated with pieces of caseous material which have been carefully excised with sterilised instruments; care must be taken to thoroughly break up the caseous tissue in the agar; as it is a very slow growing organism the tubes must be capped to prevent drying whilst in the incubator. The growths are very characteristic, being mealy, scaly or heaped up. We have already (p. 454) given the staining methods for cover-slip preparations of sputum and sections.

Tuberculosis is widely spread amongst the domesticated animals, especially cattle and fowl; but cats, dogs, sheep and goats, are not often attacked.

The danger of infection from tubercular meat and from milk is one of great importance for the hygienist. It has now been shown by many observers that tuberculosis follows the ingestion of tubercular meat, and not only from obviously tubercular parts, but of meat which, though it appears healthy, has been obtained from an animal suffering from tuberculosis. Between the sanitary authorities and the butchers, disputes are always taking place as to what is general tuberculosis and what is local, and whether carcases, from which the peritoneal membranes, the seat of most pronounced tubercle, have been stripped should be sold as good meat, when to the eye they show no obvious signs of disease. Concerning these questions it may be said that all the most recent and careful scientific evidence shows clearly that there is a very grave danger in consuming the meat or drinking the milk of animals

(bovines) affected with tuberculosis. It is true of course that the danger of infection is lessened by proper cooking, and by the fact that not all individuals are equally susceptible to tubercle; still for the few the danger is great. There appear to be medical men, who for some reason draw sharp lines between the more local and the more generalised forms of tuberculosis, and who in consequence ascribe no danger to the meat in the former case. The same class of men would see no harm in the consumption of milk from cows which although the mammæ were not tubercular, were yet suffering from tuberculosis. We maintain, however, that the evidence, and that of the most recent date, shows that there is danger. The criminality of selling the milk of cows suffering from tubercular mammitis is, of course, too obvious to need further comment.*

Actinomycosis.—This disease is much more local than tuberculosis: like tubercle it leads to necrosis, caseation and suppuration. It is common as an affection of the jaws and tongue in bovines; in man the disease may readily be recognised by the presence of sulphur yellow specks in the discharges. Closely allied to this disease is the madura disease of India, which is extremely chronic and almost exclusively limited to the feet. Infection in cattle appears most commonly from the mouth; in India in the case of the madura disease it is the exposed foot. The fungus is higher in the scale than the schizomycetes, having affinities with the hyphal fungi. In sections it has a very typical ray form, and hence the name of ray fungus. The rays are

* Even in these cases there are probably men who if in a cover-slip preparation of the milk they do not find a bacillus would declare it wholesome; they might on the same principle maintain the purity of a caseous mass.

usually in the form of clubs, whilst the centre consists of delicate hyphæ; spores are formed. When one of the sulphur yellow specks mentioned above is crushed under a cover-slip and examined, its fungus nature is readily seen. It may readily be stained by the method of Gram, fuchsine or by the blues. The tissue reaction is a granuloma closely resembling that seen in tubercle. It may be mentioned that the colour of the fungus may vary from yellow to black, or be in the young stage nearly colourless.

Inoculation on agar, gelatine or glycerine agar, or broth, may readily be performed, provided that the fungus be *thoroughly* broken up with the sterilised spatula. The growth on the solid media is characterised by a scab or crater-like appearance.

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